THE DERIVED DEMAND FOR IMPORTED DAIRY PRODUCTS IN SELECTED INTERNATION MARKETS

By

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Abstract of Dissertation Presented to the Graduate School
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THE DERIVED DEMAND FOR IMPORTED DAIRY PRODUCTS IN SELECTED INTERNATION MARKETS

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This study assesses the competitiveness of U.S. dairy products in selected international markets considered to be potential major importers of dairy products and particularly U.S. dairy products. Given the total elimination of dairy price supports by January 1, 2000, and given the 21 percent quantity and 36 percent expenditure reduction in subsidized dairy exports, U.S. producers of dairy products have gained interest in obtaining a greater market share of international markets.

A primary objective of this study was to develop the differential approach to the theory of the firm and to present the methodology of how it can be applied to the derived demand for imported dairy products. Additional objectives of this study were to project future derived demand for dairy products in the selected international markets and to simulate the effects of trade liberalization.

Forecasts based on 1994-98 averages and forecasts given the reduction in export subsidies indicate that Australia and New Zealand will be the primary gainers in terms of the quantity of dairy products imported. However, the percentage increase for imports of products from the U.S., the European Union (EU), and the rest of the world (ROW) was greater in some instances. For imports of whey into Japan, the EU was expected to be the primary gainer in terms of both quantity and percent. Of all the forecasts, given EU subsidy reductions and EU and U.S. subsidy reductions for Mexico, imports of whey into Japan and cheese into Hong Kong are the only instances where imports from the U.S. showed significant increases. Given aggressive reductions (72 percent) in subsidies, imports of whey into Japan were expected to increase by 43 percent and imports of cheese into Hong Kong were expected to increase by 19 percent, the largest percentage increase of all countries. Imports of U.S. products other than cheese and whey showed little or a negative change. In the case of Mexico's imports of butter, U.S. subsidy reductions resulted in a smaller percentage decrease in imports when compared to the decrease for the EU.

CHAPTER 1
INTRODUCTION, PROBLEM STATEMENT, AND OBJECTIVES

Introduction

The United States (U.S.) is the largest milk-producing country in the world; however, from 1990 to 95, U.S. dairy exports ranged from 2,546 to 7,032 million pounds, which ranked the U.S. tenth among dairy exporters in 1995. Furthermore, U.S. dairy exports accounted for only 4.1 percent of total domestic milk production in 1995. The reason for this occurrence is that exports have been relatively unattractive due to the large domestic market and prices offered by the United States Department of Agriculture (USDA) under the dairy price support program through the Commodity Credit Corporation (Dobson, 1995).

As a result of the Federal Agriculture Improvement and Reform Act of 1996 (FAIR Act), dairy price supports will be phase out by January 1, 2000.[1] As a result of the General Agreement on Tariffs and Trade (GATT), subsidized dairy exports will be reduced by 21 percent by the year 2000 and monetary outlays on dairy subsidies will be reduced by 36 percent, with more reductions expected as trade negotiations continue.[2]

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[1] U.S. price supports for dairy products were provided primarily through government purchases of nonfat dry milk, cheese, and butter.

[2] The Uruguay Round GATT agreement mandated reductions are based on average subsidized quantities and expenditures for the years 1986-1990. These reductions

These changes in policy have made gaining a larger share of world dairy exports more important to U.S. producers/processors. Evidence of this concern is the willingness of the industry to fund the U.S. Dairy Export Council (USDEC). USDEC is in its third year of existence and has a 1997 budget of $7,835,000 with nine offices located in nine countries around the world.

The major players in the international dairy export market are the European Union (EU), New Zealand, Australia, and the U.S. In 1997, the EU had the largest market share of world dairy exports at about 34 percent. New Zealand, Australia, and the U.S. each had 22, 13, and 6, percent respectively. This was a significant difference from 1990 where the EU had 47 percent, and New Zealand, Australia, and the U.S. each had 19, 8, and 4 percent, respectively (Food and Agricultural Organization of the United Nations Statistics (FAO Statistics, 1999).[3]

Of the major dairy exporters, the U.S. and the EU subsidize exports. However the EU budget for dairy export subsidies from 1990-1995 was $3.4 billion, nearly 15 times the U.S. budget for that same period. For the year 2000, of the total export subsidies allowed under the World Trade Organization (WTO), 72 percent of that total is permitted to the European Union while only 3 percent is permitted to the U.S. (USDEC, 1998c).[4]

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applied to all nations that subsidized dairy exports.

[3] Percentages of total world dairy trade were on a milk-equivalent basis.

[4] The WTO has allowed for a world total of 51.26 billion milk-equivalent lbs. of dairy products to be subsidized. This is projected to be 58% of world dairy trade for the year

Problem Statement and Objectives of Research

The changing domestic environment has increased the U.S. interest in becoming a major supplier in the international arena. U.S. price supports for dairy products have been reduced steadily for the past 15 years. As a result, small-scale farmers are becoming fewer while large-scale dairy operations, often milking several thousand cows, are remaining due to cost competitiveness. Milk products produced from these dairy operations milk are capable of competing in international dairy markets (Vitaliano, 1995). This current situation should persist as price supports are phased out totally.

World trade liberalization, particularly the mandated GATT reductions in dairy export subsidies has also increased U.S. interest in the international arena. Export subsidy removals should likely increase world prices for dairy products, thereby making the world market more attractive to U.S. producers/processors (Dobson, 1992). Given that the U.S. maintains a small share of total subsidized dairy exports, it is in a good position to gain greater access to international markets that will likely be given up by the EU as subsidy reductions continue.

Given the increased emphasis on the export market, the U.S. dairy industry is in need of demand information by country and by individual dairy product. Import demand work for various countries (Dobson, 1992; Dobson, 1995; Zhou & Navakovic, 1996) has been minimal and qualitative in nature. Furthermore, USDEC chose target markets and products based on a *qualitative analysis* of commercial and economic factors. However, USDEC is in need of a *quantitative analysis* of import demand for various countries in

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2000.

order to provide the U.S. dairy industry with the demand characteristics of their chosen markets.

Given the recent changes in the domestic and international policy environment, the U.S. dairy industry is positioning itself to become a major supplier in the international arena. For this to transpire, import demand information is needed to help allocate valuable resources to the most promising markets. Given that exports have been a small share of total production and that the U.S. has maintained a relatively small share of milk traded, there is little quantitative information on import demand. Therefore estimating import demand relationships for intended importing destinations is needed in order to achieve the objective of becoming a major international supplier.

The major goal of this project is to provide the U.S. dairy industry with empirical estimates of the sensitivity (elasticities) of milk products purchased by Hong Kong, Japan and Mexico from individual exporting sources (U.S, EU, Australia, and New Zealand) with respect to price changes and total import changes. These estimates will then be used to assess the relative competitiveness of U.S. dairy products in major importing markets relative to other major dairy exporters. Past studies that assessed the demand for imports differentiated by source country of production have used a utility or consumer approach to obtain import demand equations. However, given that imported dairy products are purchased by firms, and that a significant amount of transformation and/or value added takes place after goods reached the importing country, this study will estimate demand from a production approach where imports are inputs into production processes. Specific objectives are:

1. To mathematically derive the differential factor demand model that will be used to estimate the import demand for dairy products differentiated by source of production, where the theoretical foundation of this model will be production theory instead of consumer theory.
2. To econometrically estimate the derived demand for imported dairy products in Hong Kong, Japan, and Mexico by type of product and by source country of production;
3. To utilize the empirically estimated import demand parameters to provide empirical measures of the sensitivity of demand for dairy products to changes in total imports, own price, and the prices of cross country substitutes;
4. To utilize the empirically estimated derived demand parameters to project short run future derived demand for imported dairy products in the selected countries; and
5. To estimate the effects of export subsidy reductions on the derived demand for imported dairy products in the selected countries.

Overview of Study

Chapter 2 provides a situation and outlook for world dairy trade and an overview of world dairy trade policy resulting from the Uruguay Round GATT agreement and regional trade agreements such as the North America Free Trade Agreement (NAFTA). Also included in Chapter 2 is an overview of the major exporting countries considered in this study. Lastly, this chapter covers macroeconomic factors, consumption, production, trade, and import policies in Hong Kong, Japan, and Mexico.

Chapter 3 provides the theoretical base for and presents the differential production approach to the import demand for dairy products. In this chapter, the theoretical and applied justification for using a production approach to import demand is presented. An overview of the theory of the firm is presented as well. However, the primary focus of this chapter is the mathematical derivation of the differential factor demand model and its application to the derived demand for dairy imports differentiated by the source country of production.

Chapter 4 develops the econometric model and reviews econometric issues relevant to the estimation of the differential factor demand model. Issues such as model parameterization, estimation techniques, goodness of fit measures, autocorrelation, and hypothesis testing are reviewed. Also included in this chapter is a section on forecasting and simulations. This topic is particularly important because the differential approach results in a dependent variable that can not be used directly to forecast demand. Forecasting with these models requires special attention.

Chapter 5 presents the methodology and procedure use to accomplish the specific objectives. Of the information presented in chapters 3 and 4, this chapter presents the econometric and theoretical methods actually used in this study. A highlight of this chapter is the methods employed to do the actual forecast and simulation. This chapter presents a new methodology that can be employed to forecast with differential models.

Chapter 6 presents the empirical results of the estimation procedure. These include parameter estimates, elasticities, hypotheses testing results, and forecast and simulation results.

Lastly, Chapter 7 provides a summary and conclusion of the research.

CHAPTER 2
WORLD DAIRY SITUATION AND OUTLOOK

World Production of Milk and Milk Products

World production of milk is forecast to rise to 615 million tons by 2005, representing an average annual increase of slightly over 1 percent for the period 1995-2005. The driving force behind the expected growth is improvements in technological and nutritional factors which will result in higher milk yields per cow (Griffin, 1999). The U.S. Dairy Export Council (USDEC) projects an increase in milk production as well. USDEC foresees world milk production increasing by a total of 6 percent for the period 1997 to 2007 (USDEC, 1998d).

World production of fresh milk in 1998 was 470,172,743 metric tons (mt.), up nearly two-thirds of a percent from 1997 (466,724,901 mt.). From 1961 to 1998, world fresh milk production has been increasing by 1.11 percent per year on average. Average yearly production growth in the 1960s, 70s, and 80s was 1.54, 1.63, and 1.27 percent respectively, indicating strong growth in milk production in those decades. Since 1990, fresh milk production has been declining on average by .23 percent per year; however, for the last two years production has been increasing (Table 2-1).

World butter production in 1998 was nearly 6.7 million mt. This was up three-quarters of a percent from butter production in 1997 (6.64 million mt.). Overall, world

Table 2-1 World milk and milk products production (metric tons): 1961-1998

Year	*Fresh Milk*	*Butter*	*Cheese*	*Dry Milk (Skim)*	*Dry Milk (Whole)*	*Dry Whey*
1961	313,628,329	5,340,194	5,432,626	1,735,905	499,693	229,241
1965	332,276,293	5,812,807	6,306,158	2,288,991	717,149	337,593
1970	359,322,664	5,718,933	7,736,167	2,958,127	940,182	526,592
1975	387,717,681	6,320,412	9,430,273	4,015,623	1,195,129	847,926
1980	422,447,703	6,934,604	11,504,996	4,177,811	1,726,792	1,089,748
1985	458,777,640	7,534,375	13,151,689	4,621,749	1,959,829	1,361,098
1990	479,101,237	7,790,321	14,824,575	4,249,059	2,085,452	1,573,665
1995	464,450,507	6,597,868	14,504,548	3,470,280	2,449,773	1,798,029
1996	464,378,702	6,586,079	14,897,649	3,386,037	2,384,442	1,812,967
1997	466,724,901	6,638,553	15,151,865	3,450,571	2,477,736	1,815,366
1998	470,172,743	6,695,971	15,186,716	3,429,449	2,559,276	1,852,746
Average Annual Growth				*Percent*		
1961-1998	1.11	0.66	2.84	2.10	4.62	6.01
1961-1970	1.54	0.81	4.02	6.33	7.33	9.80
1971-1980	1.63	1.96	4.06	3.62	6.38	7.99
1981-1990	1.27	1.22	2.57	0.44	2.00	3.76
1991-1998	-0.23	-1.84	0.32	-2.48	2.66	2.10

Source: Food and Agricultural Organization of the United Nations Statistical Database (FAO Statistics) (1999)

butter production has increased by two thirds of a percent per year on average since 1961. Significant increases in world butter production occurred in the 1970s and 1980s where the average increase per year for those decades were 1.96 and 1.22

percent respectively. In the 1990s butter production declined by 1.84 percent per year on average (Table 2-1).

World cheese production in 1998 was nearly 15.2 million metric tons. This was up .23 percent from production in 1997. In the 1960s and 70s, growth in world cheese production was phenomenal. During these decades cheese production grew on average by slightly over 4 percent per year. Average yearly growth slowed in the 1980s to 2.57 percent per year and further slowed to .32 percent per year in the 1990s. Since 1961 world cheese production has grown by nearly 3 percent per year (Table 2-1).

World dry skim milk production (non-fat dry milk or skim milk powder) in 1998 (3,429,449 mt.) was down slightly from 1997 (3,450,571 mt.) by .6 percent. Of all the products considered, dry skim milk has had the sharpest decline this decade. Since 1991 world production of dry skim milk has been declining by 2.5 percent per year on average. However, dry skim milk production overall has been increasing on average by 2.1 percent per year since 1961 until 1998, with the biggest surge in production being in the 1960s where production increased by 6.33 percent per year (Table 2-1).

Growth in world production of dry whole milk has been phenomenal. From 1961 to 1998, production has grown by 4.62 percent per year on average, and increased of 7.33 and 6.38 percent per year in the 1960s and 70s respectively. Average yearly production growth in the 1980s slowed to 2 percent and increased two-thirds of a percent in the 1990s to 2.66 percent. Overall, dry whole milk production has been increasing steadily. In 1998, production was 2.56 million mt., up 3.2 percent from 1997 (2.48 million mt.) (Table 2-1).

The most growth in the production of milk and its products has occurred in the dry whey market. From 1961 to 1998, average yearly growth in world dry whey production has been 6 percent per year. In the 1960's and 70's world production grew on average by nearly 10 and 8 percent per year respectively. In this recent decade, growth has slowed considerably to 2.66 percent per year on average. Like dry whole milk, whey production has been steadily increasing as well. In 1998, whey production was 1.85 million mt., which was up 2.1 percent from 1997 (1.82 million mt.) (Table 2-1).

World Trade in Dairy Products

According to USDEC (1999b), over the next decade growth in world demand for dairy products should exceed that of milk production. As a result, world prices should strengthen and new trade opportunities in international markets should emerge. As trade barriers and export subsidy levels are phased down and world demand increases, there is clear opportunity for the U.S. to become a more significant player in the international arena (USDEC, 1999a).

In 1998, dairy markets were plagued by oversupply, economic crises weakened world demand, and high subsidy levels continuously exerted downward pressure on market prices. However, prior to the upheaval in world financial markets there was an upward trend in the demand for many dairy products. It is likely that these trends will continue as markets become more stable, and demand will continue to increase beyond world production resulting in increase trade (USDEC, 1999a and 1999b).

Table 2-2 World trade in milk and dairy products: 1961-1999

	Total Exports (Milk Equivalent Lbs.) [a]	
Year	*Mt.*	*$1000US*
1961	13,206,407	1,251,722
1965	17,085,278	1,804,231
1970	23,604,161	2,254,152
1975	25,231,152	5,836,580
1980	42,888,680	12,905,987
1985	48,051,399	10,974,166
1990	46,545,399	18,620,423
1991	50,633,236	19,475,537
1992	55,897,859	22,831,673
1993	56,652,255	22,020,862
1994	59,179,436	23,189,558
1995	62,066,111	26,948,371
1996	60,589,261	27,316,545
1997	64,508,469	26,026,220
1998	64,166,098	25,579,573
Average Annual Growth	*Percent*	
1961-98	4.68	9.18
1961-70	6.81	6.88
1971-80	6.71	19.26
1981-80	1.18	5.33
1991-98	4.10	3.99

[a] Includes re-exports and excludes intra-EU trade
Source: FAO Statistics (1999)

According to the FAO, world import demand for dairy products could reach 44 million tons in 2005. This is an increase of 9.5 million tons when compared to the average production from 1993 to 1995. However, the proportion of milk traded will likely only represent 7 percent of world production (Griffin, 1999).

Total trade in dairy products in 1998 was 64,166,098 mt. This was down one-half of a percent from 1997 (64,508,469 mt.). Overall, growth in world dairy trade has been strong. For the period 1961 to 1998, total world exports have been increasing by 4.7 percent per year on average. Growth in world exports in terms of nominal value has been on average increasing by 9.2 percent per year. The largest growth in world exports in terms of both quantity and value occurred in 1960s and the 1970s. In the 1960s, exports grew by 6.8 percent per years on average and grew by 6.7 percent per on average in the 1970s. In terms of value, world dairy exports grew by a phenomenal 19.26 percent per year on average in the 1970s (Table 2-2).

In comparing Table 2-1 and Table 2-2, the potential for increased trade becomes apparent. The average yearly growth in the quantity of milk and products exported for the period 1961 to 1998 is over four times the average growth in fresh milk produced, six and a half times the growth in butter produced, nearly twice the growth in cheese produced, and over two times the growth in skim milk powder production. When comparing the growth in dairy exports to the growth in production this current decade (1991-1998), the potential for dairy exports becomes even more apparent. In Table 2-1, the highest production average annual growth rate is 2.66 percent (whole dry milk). This is still nearly two percent lower than the export growth rate for all milk traded (4.10 percent) for that same period. Although the percent of dairy production that enters into world trade is currently about 5 percent, these trends in production and export growth is the driving force behind world trade being projected to be 7 percent of total production within the next ten years (Griffin, 1999)

World Dairy Trade Policy

The 1994 Uruguay Round (UR) General Agreement on Tariffs and Trade (GATT) agreement marked the first time in history that agriculture as a sector was considered for trade liberalization. Since the inception of the GATT agreements in 1947, the agricultural sector has always been considered a special case and was to some degree exempt from round negotiations. The reason for agriculture's exemption was because many nations considered agriculture as a declining sector and thought that full exposure to the rigors of international competition would lead to unacceptable social and economic disruption. As a result, articles were written in past GATT agreements that allowed for export subsidies, import restrictions, and trade distorting domestic support in agricultural products, although these policies where considered illegal in other sectors (Organization for Economic Cooperation and Development (OECD), 1995).

The main elements of the UR GATT Agreement on agriculture are: (1) market access, (2) domestic support commitments, (3) export competition commitments, (4) export restrictions, (5) sanitary and phytosanitary measures, and (6) the World Trade Organization (WTO) Agreement (OECD, 1995).

The main provisions of the UR market access commitment are as follows. All non-tariff barriers such as import quotas, licenses, and variable levies are to be converted to tariffs that are based on the difference between average 1986-88 internal prices and world market prices. All tariffs are to have a maximum bound and be reduced by an average of 36 percent over a six-year period with a 15 percent minimum reduction in all tariffs.[1]

The domestic support commitments require that all participating countries measure domestic support by the "Total Aggregate Measure of Support" (Total AMS). For developed countries, the Total AMS is to be reduced by 20 percent of the Total AMS in 1886-88 over the implementation period, and for developing countries, the reduction is 13 percent by 2005.

Export competition commitments require that all goods exported under subsidies be in accordance with those goods specified under the UR agreement. This commitment further requires that expenditures for export subsidies be reduced by 36 percent over the six-year implementation period and that the quantity exported under subsidy be reduced by 21 percent over that same period.[2]

Export restriction provisions require that exporting countries consider the food security of importing countries and give adequate notice when exports are to be restricted. The provisions concerning sanitary and phytosanitary measures give countries the right to restrict trade for the purpose of protecting the health and lives of humans, animals, or plants. Lastly, the UR agreement established the WTO which serves as the dispute settlement body for international trade (OECD, 1995; Zhu et al., 1998).

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[1] Developing countries are to reduce tariffs by 24 percent over a 10-year period with a minimum reduction of 10 percent.

[2] Developing countries are to reduce expenditures by 24 percent and quantities by 14 percent. Reductions are based on the average expenditures and quantities in 1986-1990.

Although the previous commitments apply to most agricultural products, the dairy sector still remains highly protected. In major importing markets tariffs rates are still very high. Many tariff peaks for dairy products in developed countries are well over 100 percent while some are as high as 370 percent in countries like Japan and Canada. Trade distorting domestic policies still exist to a large degree, and the amount of subsidies allocated to countries in the final year of the UR implementation period is still projected to be 58 percent world trade in dairy (Konandreas, 1999).

The formation of regional trade agreements is legal under the GATT as long as they do not raise new trade barriers to nations outside of the agreement. Zhu et al. (1998) lists five main forms of regional economic integration that may result from regional trade agreements. These are as follows:

1. The establishment of preferential tariffs that allows imports from regional countries to enter at lower tariff rates;
2. The elimination of tariffs between regional countries while keeping tariffs for the rest of the world;
3. A customs union in which trade is free among members and members adopt a common external tariff toward non-members;
4. A customs union allowing free movement of labor, capital and other production factors;
5. An economic union, a common market with harmonized fiscal, monetary and other economic policies.

Although there are a number of regional trade agreements that affect world dairy trade, the regional agreement relevant to this study is the North American Free Trade Agreement (NAFTA). NAFTA is a commitment between the US, Canada, and Mexico that was established in 1994. Currently there is an agreement on dairy trade between Mexico and the US. A dairy agreement with Canada has not yet been reach (Zhu et al., 1998). Specific regulations of NAFTA pertaining to dairy trade between Mexico and the U.S. will be presented in later sections.

U.S. Dairy Situation and Outlook

In 1990, dairy exports on a total solid basis represented only 1.7 percent of U.S. milk production. By 1995, the percentage of total milk production that was sold in the export market increased to 4.1 percent, indicating the U.S. dairy industry's increase activity in international markets (USDEC, 1997a). Major changes in the domestic and international environment that have encourage such activity are

1. The elimination of the USDA's price support program by the year 2000,
2. The U.S. dairy market is a mature market that is fiercely competitive with no prospect for growth,
3. NAFTA has expanded dairy exporting opportunities in Mexico due to preferential tariffs , and
4. The UR GATT agreement, which opened heavily restricted markets and reduced the use of export subsidies.

As a result of the recent GATT agreement reducing export subsidies, it is expected that the large market share of dairy exports currently held by the European

Union (EU) will decrease over time. Access to loss market share by the EU will require that the U.S. dairy industry aggressively pursue international markets (Dobson, 1997).

U.S. Milk and Milk Products Production

In 1998, U.S. fresh milk production was 71.4 million metric tons. This was up 3.2 percent when compared to the average production in 1991 to 1997. Overall, U.S. fresh milk production has been growing steadily this decade. For the period 1991 to 1997, milk production has grown on average by nearly 1 percent per year (Table 2-3).

U.S. butter production has been sharply declining since 1991. From 1991 to 1997, butter production has been declining on average by nearly 2.8 percent per year. In 1998, butter production continued to decline. Production for that year was 500,000 metric tons, which was nearly a 16 percent decline when compared to 1991-97 average production (Table 2-3).

For the period 1991 to 1997, average cheese production in the U.S. was 3,409,824 metric tons. For that same period average growth per year was 2.65 percent. In 1998, U.S. cheese production continued to increase when compared to the average in 1991-97. Cheese production that year was 3,733,500 metric tons, which was up 9.5 percent from the previous year (Table 2-3).

Although world whey production has been increasing and represents the fastest growing market of all dairy products, dry whey production in the U.S. has been declining. Since 1991, dry whey production has been declining by .37 percent per

Table 2-3 US milk and products production: 1991-98

	Average Production	*Average Annual Growth*	*Production*
	1991-97 *Metric tons*	*1991-97* *Percent*	*1998* *Metric tons*
Whole Fresh Milk	69,216,143	0.93	71,414,000
Butter	593,904	-2.79	500,000
Cheese	3,409,824	2.65	3,733,500
Dry Whey	533,905	-0.37	535,160
Dry Whole Milk	66,421	4.93	61,000
Dry Skim Milk	509,460	5.86	537,400

Source: FAO Statistics (1999)

year; however, whey production in 1998 may be an indication of recovery. In 1998, production was 535,160 metric tons, which was up a quarter of a percent (Table 2-3).

U.S. production in milk powders has been growing at a phenomenal rate since 1991. For the period 1991 to 1997, production in whole and skim milk powders has grown on average by 4.9 and 5.9 percent per year, respectively. In 1998, U.S. dry whole milk production was 61,000 metric tons, which was down significantly from the decade average of 66,421 metric tons by over 8 percent. Dry skim milk production in 1998 was 537,400 metric tons, which was up nearly 5.5 percent when compared to 1991-97 (Table 2-3). Overall, with the exception of the dry whey and butter markets, U.S. production of milk and its products has been strongly increasing this decade.

U.S. Trade in Dairy Products

In 1998, total U.S. dairy exports was 2,197,385 metric tons (milk equivalent lbs.) and was valued at 524 million dollars. This was up 3.14 percent when compared to total exports in 1997. However, due to depressed world prices in 1998, this was down by 3.74 percent in terms of value. Overall, growth in U.S. dairy exports in terms of quantity and value has been strong. Total U.S. dairy exports have grown on average by 11.5 percent per year in quantity and 16.4 percent per year in value during the period 1991 to 1997 (Table 2-4).

U.S. butter exports in 1998 was 9,024 metric tons and was valued at 14.4 million dollars. This was down sharply when compared to exports in 1997. Total butter exports in 1998 was down 43 percent in terms of quantity and down 48 percent in terms of value. This was primarily due to exports of butter in 1997 being boosted by the United States Department of Agriculture (USDA) aggressive use of the Dairy Export Incentive Program (DEIP) (USDA-Foreign Agricultural Service, 1998a). With the exception of 1998, U.S. butter exports have been growing this current decade. From 1991 to 1997, the quantity of U.S. butter exports grew on average by 12 percent per year and the value of U.S. exports grew by 18 percent (Table 2-4).

US cheese exports in 1998 was 40,592 metric tons, which was up 1 percent when compared to 1997; however, in terms of value this was down 4.7 percent. Since 1991, growth in cheese exports from the U.S. has been strong. For the period 1991 to 1997, the quantity of cheese exported from the U.S. grew on average by 20 percent per year and the value grew by 22 percent per year (Table 2-4).

Table 2-4 U.S. exports of dairy products: 1991-98

		Average Exports	*Exports*	*Average Annual Growth*	
		1991-97	1998	1991-97	1997-98
Milk Equivalent	*Mt.*	2,015,886	2,197,385	11.5	3.14
	$1000US	485,723	524,058	16.4	-3.74
Butter	*Mt.*	57,651	9,024	11.8	-43.10
	$1000US	87,877	14,356	18.2	-47.84
Cheese	*Mt.*	26,085	40,592	19.8	1.08
	$1000US	87,422	130,581	20.8	-4.68
Milk Dry	*Mt.*	88,586	124,335	45.1	11.87
	$1000US	148,273	193,080	54.0	3.67
Dry Whey	*Mt.*	88,686	120,512	8.8	3.05
	$1000US	80,759	113,238	13.0	-2.39

Source: FAO Statistics (1999)

Total U.S. dry milk exports in 1998 was 124,335 million metric tons. This was up 11.87 percent when compared to the quantity exported in 1997 and up 3.7 percent when compared to the value in 1997. Growth in dry milk exports has been incredible this decade. For the period 1991 to 1997, U.S. exports of dry milk have been growing at a rate of 45 percent per year on average in terms of quantity and 54 percent per year in terms of value (Table 2-4). To some degree this can be attributed to the DEIP. In 1996, DEIP exports only accounted for about 15 percent of total dairy exports and exports reach record lows for the decade (USDEC, 1998b). As a result of the USDA's aggressive use of DEIP in 1997, dry milk exports increase by 206 percent (USDA-

FAS, 1998a). The same occurred in 1992 when DEIP exports increased from 50 percent to 70 percent (USDEC, 1998b).

1998 exports of dry whey were 120,512 metric tons and valued over 113 million dollars. In terms of quantity exported this was up by 3 percent when compared to 1997 exports and down 2.4 percent in terms of value. Overall, dry whey exports have been growing by 8.8 percent per year on average from 1991 to 1997, and the value has grown by 13 percent per year on average. The driving force behind this growth was exports in 1995, which were up 60 percent when compared to 1994.

US Dairy Industry and the WTO and NAFTA

Both the UR GATT agreement and NAFTA address issues of market access, which involves the tariffication of non-tariff barriers. Both agreements are also committed to the reduction and eventual removal of export subsidies and the reduction of trade distorted domestic support. It is believed by the U.S. dairy industry that these policies will lead to the deregulation of major importing markets, reduce the market share of the EU through subsidy reductions, and decrease production in foreign markets that heavily subsidize dairy production, leading to even a greater potential for increased imports. However, given that dairy imports into the U.S. were highly restricted by import quotas, subsidized exports accounted for as much as 90 percent of exports in the mid 80's and 50 percent in the 90's, and given that the U.S. dairy industry was highly subsidized, these policies will directly effect the U.S. as well.

As a result of NAFTA, import restrictions on milk powder and cheese coming from Mexico were relaxed. When NAFTA went into effect, the U.S. established an initial tariff-rate quota (TRQ) of 422 metric tons for imports of milk powder from Mexico. The quota limit grows at a 3 percent compounded annual rate over a 10-year transition period. U.S. imports from Mexico within the quota limit enter duty free. Imports in excess of the quota are assessed a tariff equivalent based on past import restrictions of milk powder. The over quota tariff limit was set at no less than 78-83 percent ad valorem which is to be phased-out over 10 years. U.S. imports restrictions on Mexican cheese were replaced with a TRQ as well. The initial quota limit was set at 5,550 tons and has grown by 3 percent per year compounded annually. In quota quantities of cheese from Mexico enter duty free and above quotas quantities are assessed a tariff of 69.5 percent that is to phased out over ten years. Similar import policies were enacted in Mexico as well; however, these will be discussed in a later section. Since the enactment of the NAFTA, U.S. imports from Mexico have been negligible (USDA-FAS, 1999a).

The market access commitment to the WTO requires that the U.S. replace import quotas on dairy product with tariff equivalents, which will be reduced by a minimum of 15 percent over 6 years beginning in 1995. The tariffs for major traded products are 101.8 cents/kg for non-fat dry milk, 181.3 cents/kg for butter, and 144.3 cents/kg for cheese. At the end of the implementation period the tariff on non-fat dry milk will be 86.5 cents/kg, 154.1 cents/kg for butter, and 122.7 cents/kg for cheese. The initial TRQ quota limit for cheese was 110,999 tons and it will increase to 141,991 tons by the year 2000. TRQ's for all other products accounted for 13,700 tons of milk fat and 16,100 tons of non-fat solids in the first year and will increase to 22,785 tons and 26,825 tons respectively by the year 2000 (USDA-FAS, 1999a).

In the final year of commitment to the WTO, the U.S. is required to reduce the quantity of DEIP assisted exports by 21 percent and total subsidy expenditures by 36 percent. These reduction are based on the average subsidized quantities and expenditures from 1986-1990 (USDA-FAS, 1999a). In 1995, the maximum amount of butter, non-fat dry milk, cheese, and other products that could be exported with subsidy was 43, 108.2, 3.7, and 12.5 1000-tons respectively. These are to be reduced to 21.1 68.2, 3 and 2.5 1000-tons for butter, non-fat dry milk, cheese, and other products respectively by the year 2000 (Konandreas, 1999).

Since the enactment of NAFTA and the UR GATT, net-exports of all dairy products in milk equivalent pounds have been extremely variable. Annual changes in net-exports since 1993 range from an increase of 161 percent in 1997 to a decrease of 75 percent in 1996. Overall, net exports have increased by 11 per year on average since 1993 (FAO Statistics, 1999).

The primary U.S. dairy import is cheese. For quite some time the U.S. has been a net-importer of cheese. Since the enactment of NAFTA and the UR GATT, net imports of cheese decreased by over 5 percent per year on average from 1993 to 1997. Due to a 19 percent increase in imports and a 1.1 percent increase in exports in 1998, net-imports of cheese increased by 26.6 percent, resulting in an overall average percent increase in net-imports of cheese of 1.22 percent (FAO Statistics, 1999).

For the period 1993 to 1998, growth in U.S. exports of all dairy products has out-paced U.S. imports. This pattern indicates that although the U.S. is opening up its dairy markets to the rest of the world, trade deregulation has led to increases in dairy exports. Even in the presence of the peso devaluation and the Asian economic crisis that affected imports into Mexico and Japan respectively, which are two of the top dairy export markets for the U.S., exports of dairy products have still increased under NAFTA and the UR GATT.

Overview of the European Union

The European Union (EU) is a cooperation between 15 countries with the primary purpose of harmonizing fiscal, monetary, and other economic policies. As a unit, the EU accounts for over 25 percent of world cow milk production and about 40 percent of world trade (USDEC, 1996). The reasons for the EU's dominance in world dairy markets are their government farm income support policies which includes price supports, export subsidies, and import restrictions (Zhu, et al., 1998). Given current and potential world trade deregulation, it is projected that the EU's role in dairy trade will significantly diminish within the next 10 years (Griffin, 1999; Zhu et al., 1998).

Under the UR GATT, the EU is required to reduced export subsidies in accordance with the agreed upon commitments, which is a 21 percent quantity reduction and a 36 percent expenditure reduction. Even in compliance with the UR GATT, the EU remains a large export subsidizer. Of the total amount of export subsidies permitted under the WTO in the year 2000, the EU's share is 72.1 percent. If the EU uses the full amount permitted this could represent 41 percent of total world trade (USDEC, 1998c). Additionally, the EU can satisfy GATT requirements and still subsidize 3.5 times as much non-fat dry milk and 100 times as much cheese as the U.S. (Dobson and Cropp, 1995). In 1995, EU subsidized exports allowed under the WTO were 297, 447, 407,and 1,161 1000-tons for non-fat dry milk, butter, cheese, and other dairy products respectively. By the year 2000 these are to be reduced to 243, 366, 305, and 938 1000-tons respectively (OECD, 1995). It is believed by many in the dairy industry that the UR GATT just scratched the surface in terms of the removal of export subsidies and the upcoming WTO negotiations will lead to further export subsidy removals.

The EU market access commitment to the WTO required the tariffication of its import policies. In 1995, the EU established TRQ's in non-fat dry milk, butter, cheese, and other dairy products. The 1995 quantity of skim milk powder imported at the reduced tariff rate of 475 ECU/ton was 41,000 tons. This will be increased to 69,000 tons by the year 2000. The over quota tariff rate in 1995 was 1,485 ECU/t which is also reduced to 1,188 ECU/t by the year 2000. The most significant market access commitment is the TRQ established for EU cheese imports. In 1995, the quantity of cheese that could be imported into the EU at the reduced tariff rate was 18,000 tons; however, by the year 2000 this is set to increase to 104,000 tons (USDA-FAS, 1999b).

Since the enactment of the UR GATT, EU dairy exports have grown on average by 4.3 percent per year. This was primarily driven by an 18 percent increase in 1995 and a 9 percent increase in 1997. Imports of dairy products into the EU have grown as well. Since 1994, imports have grown on average by 3.4 percent per year (FAO Statistics, 1999). These statistics suggest that the tariffication of import restrictions and the reduction of export subsidies have had some effect on imports but exports still remain strong. A reason for this occurrence is that although export subsidies were reduced by 21 percent from 1995 to 2000, the amount of export subsidies permitted to the EU is still quite high (Konandreas, 1999).

Overview of New Zealand and Australia

The Mediterranean climate makes New Zealand and Australia the most efficient milk producing countries in the world. Favorable climate and natural resource conditions allow dairy farmers to graze animals outdoors without provisions for housing and with minimal requirements for forage cropping, harvesting, and storage. Low population density in Australia also provides a cost advantage by freeing up land for farm and pasture use (Zhu et al., 1998). These factors have allowed Australia and New Zealand to be dominant forces in international dairy markets even though both countries combined produce only 28 percent of U.S. production (USDEC, 1997c).

In a comparative analysis of total cash cost per hundredweight (cwt.) for Australia, New Zealand, and the Pacific US, the pasture base systems of Australia and New Zealand resulted in feed cost per cwt. of $2.25 and $1.97 respectively, while feed cost in the Pacific U.S. was $6.74. Total cash expenses overall per cwt. were $7.42, $6.47, and $10.48 for Australia, New Zealand, and the U.S., respectively (USDEC, 1997c). Although these countries are more cost efficient, the U.S. is more technology efficient. In 1996, production per cow in the U.S. was 7,487 kg per cow, which was over twice the production per cow in New Zealand and 1.5 times the production per cow in Australia (Japan Dairy Council, 1999).

Australia and New Zealand producer subsidy equivalent (pse) measure for milk is 17 percent and 2 percent, respectively. Prior to the UR GATT, the pse for milk production was 29 percent for Australia and 2 percent for New Zealand (Meilke & Lariviere, 1999). Under the current dairy support arrangement, Australian dairy farmers pay a tax on milk consumed domestically as drinking milk and manufacturers pay a tax on milk used in dairy products for domestic sales. The money is then paid to farmers that supply milk for domestic production of non-fluid products. Milk used in exported dairy products is exempt (USDA-FAS, 1999a).

Due to New Zealand's socialist history, dairy markets were highly regulated; however, with the election of the Labor Party in 1984, economic reforms eliminated subsidized pricing and import restrictions. Currently, all milk is exported through the state trading enterprise, the New Zealand Dairy Board, which give's New Zealand some degree of monopoly power in importing markets. At present, policies are being enacted to fully privatize the New Zealand Dairy Board that would allow farmers to choose to export through the Dairy Board or alternative sources (USDA-FAS, 1999a).

Unlike the US, dairy exports account for 50 percent of Australia's total production and 80 percent of total production in New Zealand (USDEC, 1997c). Since 1994, total dairy exports from New Zealand and Australia have increased on average by 7 and 9 percent per year respectively. Australia's exports have been increasing steadily while New Zealand's exports have been highly variable since the enactment of the UR GATT. Annual changes in dairy exports range from a decrease of 8 percent in 1996 to an increase of 32 percent in 1997. Additionally, both countries have increased in market share of world dairy trade. In 1994, Australia and New Zealand's market share was 11 and 20 percent respectively. In 1998, their market share has increased to 13 and 21.2 percent respectively (FAO Statistics, 1999).

Due to cost competitiveness, economist anticipates that Australia and New Zealand will likely be the primary beneficiaries of trade deregulation (Griffin, 1999;

Konnandreas, 1999; Dobson, 1997). However, due to productivity constraints inherent in pasture base systems, Australia and New Zealand's ability to become a dominant world supplier is questionable. Currently both countries are investigating ways to increase productivity; however this will likely increase cost (USDEC, 1997c).

Overview of Importing Countries

Currently, the importing countries selected, Mexico, Japan, and Hong Kong are all among the top 20 dairy importing countries. In 1997, Mexico ranked 8th among all dairy importing countries and has been among the top 5 countries in the 1980s and early 1990s. Japan has also ranked high among dairy importers for quite some time. In 1997, Japan ranked 9th and has consistently been among the top ten importers for well over 20 years. Hong Kong is a new comer to the top 20 dairy importing countries. In 1997, Hong Kong ranked 18th, which was up from 25th in 1990. In the early 1980s, Hong Kong was not among the top 30 countries (FAO Statistics, 1999).

In 1998, total imports of dairy products into Hong Kong was 892,546 metric tons, which was down from a decade high in 1997 of 1,021,373 metric tons. However, this was still significantly higher than imports in 1990. Overall, dairy imports into Hong Kong have nearly tripled within the last 8 years. Imports into Japan and Mexico in 1998 were down from 1997 as well. However, imports into Japan have been on average higher in the later part of the 1990s while imports into Mexico have been on average lower in the later part of this decade (Table 2-5).

Table 2-5 Total imports of dairy products into Hong Kong, Japan and Mexico: 1990-1998 (milk equivalent lbs. in metric tons)

Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
Hong Kong	361,581	453,592	502,275	524,761	910,730	891,158	986,358	1,021,373	892,546
% of World Trade	0.72	0.87	0.91	0.95	1.58	1.42	1.64	1.66	1.44
Japan	1,385,821	1,823,009	1,585,744	1,462,781	1,600,191	1,840,869	1,631,380	1,682,568	1,594,981
% of World Trade	2.77	3.48	2.87	2.64	2.77	2.93	2.72	2.74	2.57
Mexico	2,726,226	1,142,855	2,450,155	2,726,246	2,289,942	1,689,224	1,912,993	2,121,080	2,021,171
% of World Trade	5.44	2.18	4.43	4.91	3.97	2.69	3.18	3.45	3.26

Source: FAO Statistics (1999)

Hong Kong

In the 1990s Hong Kong has emerged as a major dairy importer, particularly in the whole milk powder and whey markets. Currently, Hong Kong is ranked 11th among dairy importing countries for whey and 7th for whole milk powder. This was up significantly from the 1980's when Hong Kong ranked 31st and 37th for whey and whole milk powders respectively. For butter, cheese, and non-fat dry milk, Hong Kong ranks 22nd, 34th, and 27th respectively (FAO Statistics, 1999). The driving force behind Hong Kong's emergence as a major dairy importer is phenomenal growth in per-capita consumption resulting from economic expansion. Also, Hong Kong is heavily influenced by western culture and it has become a major re-exporter of dairy products to other Asian countries. At present, Hong Kong's share of world dairy imports are 1.44 percent, which is twice its import share in 1990 (FAO Statistics, 1999).

Like many of the East Asian economies, Hong Kong has experienced vast economic growth. In 1987-88, real GDP growth was a remarkable 8 percent, and from 1989 to 97, GDP growth average 5 percent per year (Central Intelligence Agency (CIA), 1999; U.S. State Department, 1999). Due to Hong Kong's dependency on trade with other Asian economies that have been suffering from economic difficulties, real GDP in Hong Kong fell in 1998 by 5 percent to 169.4 billion $U.S. (CIA, 1999). Real GDP per-capita in Hong Kong in 1998 was $25,000 $US. This was down from $27,000 the previous year.

Population in Hong Kong is currently estimated at 6.7 million people, and its growth rate is estimated at 2.24 percent per year (US State Department, 1999). Of

Hong Kong's total population, over 95 percent are urban (FAO Statistics, 1999). This indicates that most homes in Hong Kong are equipped for milk storage. Also there are 15.41 migrants in Hong Kong for every 1000 natives. Migrants in Hong Kong, particular those from Western countries are a major source of dairy demand (Zhou & Novakovic, 1996).

Milk and dairy products consumption in Hong Kong tends to be higher than in any other Asian countries. This is due to greater western influence on consumer preferences and better living standards (USDEC, 1996). Growth in per-capita consumption of dairy products has been extraordinary this recent decade. Since 1991 per-capita consumption of all milk increased on average by 8.34 percent per year, and cheese, skim milk, and whole milk consumption per-capita increased on average by 6.1, 21, and 6 percent per year respectively. Butter consumption per-capita has been declining this decade by .68 percent per year (Table 2-6).

Growth in dairy imports into Hong Kong has been remarkable. For the period 1991 to 1998, total imports of milk and dairy products in milk equivalent pounds has increased on average by 14.2 percent per year. This was well over twice the average annually growth in the three preceding decades. Although per-capita butter consumption has been decreasing for the last 20 years by .5 percent per year, butter imports reached record levels this decade and has been growing by 10.3 percent annually. Imports of cheese into Hong Kong for nearly 40 years have been growing on average by over 9 percent. Dry milk import increased on average from 1991 to 1998 by 21 percent per year.

Table 2-6 Per-capita consumption of dairy products in Hong Kong: 1961-1997

Year	*All Milk*	*Butter*	*Cheese*	*Skim Milk*	*Whole Milk*	*Whey*[a]
			Kilograms			
1961	25.63	0.43	0.10	10.85	13.15	----
1965	19.89	0.47	0.10	5.34	13.42	----
1970	25.63	0:78	0.16	8.95	14.82	----
1975	32.67	0.82	0.13	15.95	14.38	----
1980	39.09	1.06	0.29	16.08	19.60	0.28
1985	39.11	0.81	0.42	2.49	33.59	1.47
1990	43.85	0.92	0.64	5.76	33.70	1.24
1991	46.61	0.75	0.65	5.61	36.56	8.95
1992	55.33	0.98	0.70	9.37	41.41	2.48
1993	53.88	1.06	0.79	10.14	37.79	----
1994	62.22	1.36	0.84	11.90	43.43	----
1995	62.79	1.17	0.81	9.68	46.93	0.36
1996	69.37	1.14	0.89	14.18	48.51	----
1997	75.71	0.72	0.96	18.39	49.47	----
Average Annual Growth			*Percent*			
1961-70	0.40	7.17	6.91	0.67	1.55	----
1971-80	4.52	7.46	8.17	6.79	3.46	----
1981-90	1.42	-0.17	8.98	3.44	6.90	32.83
1991-98	8.34	-0.68	6.09	21.07	5.91	----

[a] Most whey imports are re-exported. Whey is also use as an ingredient that is often substituted by other dry milk.

Source: FAO Statistics (1999)

The most impressive growth in imports has been in the whey market. In this recent decade whey imports grew on average by 32 percent per year, and in the previous decade grew by 88 percent per year on average (Table 2-7).

Little can be said about Hong Kong's milk production. Resources are limited and food and raw material must be imported (US State Department, 1997). As a result, Hong Kong's self sufficiency ratio for dairy products is near zero percent (USDEC, 1996).

Hong Kong pursues a policy of noninterference, particularly in customs practices. Hong Kong's ports are duty free with few trade barriers in goods and services (US State Department, 1997). Dairy imports are subject to import licensing for sanitary conditions and record keeping purposes only (WTO, 1998a).

Although the return to Chinese rule in 1997 has raised some concerns about U.S. relations with Hong Kong, it is still regarded by the U.S. as an important trade partner. Hong Kong's GDP growth and growth in per-capita consumption of dairy products are indications that dairy imports will be even greater in the future. Hong Kong is also a re-exporter of dairy products to other Asian countries, particularly China. Increased trade with Hong Kong can further expose products to the emerging dairy markets of China. Given that the EU has supplied Hong Kong in the past with over 70 percent of its dairy imports, this market will become open to potential suppliers, as the removal of export subsidies progress.

Australia and New Zealand are expected to be the primary gainers due to low cost production, closeness to Hong Kong, and an established trade history in that area. However, the demand for differentiated dairy products is increasing in Hong Kong, resulting in U.S. dairy products receiving a premium because they are perceived as high quality (Dobson, 1997;USDEC, 1996; Zhou & Novakovic, 1996). The U.S. also has a trade history with Hong Kong. In recent years the U.S. has supplied Hong Kong

Table 2-7 Hong Kong dairy imports: 1961-1998

Year	*Milk Equivalent*	*Butter*	*Cheese*	*Dry Milk*	*Whey*
			Metric Tons		
1961	75688	1410	327	3670	----
1965	75556	1787	363	2520	----
1970	117706	3102	629	6073	----
1975	146206	3773	634	9058	----
1980	211012	5546	1592	12153	104
1985	269998	4851	2435	16899	706
1990	361581	6696	4002	19382	3880
1991	453592	7064	4139	25626	8559
1992	502275	9148	4591	31384	5273
1993	524761	10388	5306	32750	4842
1994	910730	16771	6061	72384	8816
1995	891158	15798	5946	63192	14885
1996	986358	15239	6789	68593	21997
1997	1021373	11423	7718	71360	26042
1998	892546	12223	7498	63998	16662
Average Annual Growth			*Percent*		
1961-70	5.4	9.7	8.8	8.3	----
1971-80	6.4	10.4	11.4	7.4	----
1981-90	5.8	2.9	10.5	5.5	88.2
1991-98	14.2	10.3	8.4	21.2	31.9

Source: FAO Statistics (1999)

with over 20 percent of its foodstuffs, ranking the U.S. second only to China (American Consulate General, 1996).

Japan

Japan is one of the largest importers of dairy products in the world. It ranked 9th among all importing countries in total dairy products imported (in milk equivalent pounds), and ranked 5th, 7th, and 9th in imports of cheese, dry skim milk, and whey respectively in 1997. At present, Japan's share of world imports of dairy products is about 3 percent, which is about what its share has been for the last two decades. For individual dairy products, Japan's share of world imports in cheese, skim milk, and whey are about 6, 4, and 4 percent respectively. Due to the high degree of self-sufficiency in butter and whole milk, imports of these products are well under 1 percent (FAO Statistics, 1999).

Within the last 50 years, Japan has evolved from a developing country to the world's second largest economy. Currently GDP is about $5 trillion and GDP per-capita is about $36,384 (USDEC, 1998a). Overall growth for Japan has been phenomenal. Real economic growth averaged 10 percent annually in the 1960's, 5 percent in the 1970's, and 4 percent in the 1980's. However, in the early 1990's growth slowed, and due to financial difficulties with the banking system, recessions occurred in 1997 and 1998. Output in Japan began to stabilize in early 1999 as a result of emergency government spending, (CIA, 1999).

The dairy industry in Japan is relatively new. Milk and dairy products did not enter into consumers' diet until the 1920's and not to any great extent until after World War II (Simpson, 1993). However, milk is now a regular staple food that is consumed by 87 percent of all Japanese households, and is consumed by persons of all ages and genders. In Japan, milk has earned the distinction of being a "national drink" (Japan Dairy Council, 1999,).

As diets in Japan became more westernized and the health benefits of milk consumption became more known, consumption of dairy products in Japan rapidly increased. As a result, daily per-capita consumption has grown faster than any other staple food. However, when compared to developed European countries and the U.S., per-capita consumption is still relatively low. At present, daily per-capita consumption of milk is about 114g, which is roughly one third of per-capita consumption in England and less than half of per-capita consumption in the U.S. (Japan Dairy Council, 1999).

Growth in per-capita consumption of dairy products in Japan has been phenomenal. Per-capita consumption in all milk consumed annually has increased from 26.05 kg per person in 1961 to 86.05 kg in 1997. The largest growth occurred in the 1960's when per-capita consumption increased by 8.56 percent per year on average, primarily driven by a 50 percent average annual increase in skim milk. In this recent decade growth has slowed to some degree. Since 1991, growth in per-capita consumption of all milk consumed decreased by .63 percent per year; however, growth in per-capita cheese, skim milk and whey consumption continue to be strong (Table 2-8).

Dairy farming is a key sector for Japanese agriculture with raw milk production being the biggest agricultural product second only to rice. At present, there are 37,400 dairy farms in Japan, 1.86 million dairy cows, producing over 7,000 kg per cow, which is the second highest productivity rate in the world. Currently, production

Table 2-8 Per-capita consumption of dairy products in Japan: 1961-1997

Year	*All Milk**	*Butter*	*Cheese*	*Skim Milk**	*Whole Milk**	*Whey**
1961	26.05	0.14	0.1	1.27	20.17	0.46
1965	40.47	0.25	0.26	1.56	31.56	0.89
1970	53.80	0.42	0.71	8.89	44.38	1.58
1975	53.99	0.38	0.92	9.52	44.2	2.71
1980	74.32	0.56	1.2	10.47	54.49	2.62
1985	79.76	0.75	1.24	12.26	60.16	3.23
1990	82.49	0.67	1.54	11.03	63.37	3.64
1991	86.35	0.78	1.71	11.46	63.59	3.79
1992	87.48	0.79	1.77	12.87	65.7	4.06
1993	86.01	0.88	1.9	14.06	66.91	4.57
1994	84.95	0.66	1.96	11.65	64	4.87
1995	86.79	0.66	2.09	12.13	63.17	5.67
1996	86.22	0.69	2.17	12.5	63.54	5.79
1997	86.05	0.7	2.26	12.65	62.76	6.48
Average Annual Growth			*Percent*			
61-70	8.56	14.44	25.93	49.48	9.24	16.79
71-80	3.45	4.85	5.53	1.73	2.12	6.54
81-90	1.08	2.62	2.67	0.67	1.54	3.43
91-97	-0.63	1.44	5.67	2.38	-0.11	8.69

*Includes food and other uses, such as cattle feed.
Source: FAO Statistics (1999)

per cow in Japan is near that of the U.S. (7,487 kg), and is twice the rate of New Zealand and exceeds all of the EU nations. Like the U.S., the number of dairy farms has drastically decreased in the last 30 years, down significantly from the number of farms in 1965 (381,00 dairy farms). However, the number of cows per farm has increased from 3 to 4 per farm in 1965 to 49 per farm in 1998 (Japan Dairy Council, 1999).

Although Japan is a major importer of dairy products, its dairy industry is highly self-sufficient. Self-sufficiency in total dairy consumption throughout the 1980's and the early 1990's was roughly 80 percent (USDEC, 1998a; GATT, 1992). However, Japan's self-sufficiency reached a record low of 74 percent in 1996, and is projected to continue to decline to 69 percent by the year 2,000. In 1997, Japan's self-sufficiency in cheese was 40 percent, which was down from 43 percent in 1990. Self-sufficiency in whey was 38 percent down from 49 percent in 1990 (FAO Statistics, 1999).

The high degree of self-sufficiency in Japan's milk production is primarily due the to the substantial amount of government subsidies used to support domestic production. Consequently, the dairy industry is the most highly assisted livestock activity in Japan (GATT, 1992). In past years Japan's producer subsidy equivalence measure has been as high as 97 percent and on average about 85 percent over the last decade, which is nearly twice the support of the U.S. (Meilke and Lariviere, 1999). In accordance with the WTO commitment on domestic support Japan has agreed to abolish it's domestic support for the dairy industry by the year 2001 (USDA-FAS, 1999b).

Japan is the world's largest importer of agricultural products and is consistently among the top ten importers of dairy products. Growth in imports of all dairy products has increased this decade by nearly 3 percent per year on average. The

Table 2-9 Japan dairy imports: 1961-1998

Year	*Milk Equivalent*	*Cheese*	*Dry Milk*	*Whey*
		Metric Tons		
1961	283390	3227	33283	1776
1965	603242	9880	69987	3061
1970	676297	34195	64822	3322
1975	757806	48724	49647	11730
1980	1392251	74663	110747	9577
1985	1507968	81637	116815	15333
1990	1385821	107893	80721	16995
1991	1823009	124051	116873	17275
1992	1585744	128298	96556	19082
1993	1462781	136272	74092	22344
1994	1600191	143077	85995	24943
1995	1840869	157142	103332	31389
1996	1631380	164161	75163	32343
1997	1682568	171407	73697	37481
1998	1594981	183448	57086	37351
Average Annual Growth		*Percent*		
1961-70	13.4	31.9	11.0	32.2
1971-80	11.0	8.4	10.8	19.4
1981-90	0.9	4.1	-2.0	6.7
1991-98	2.7	6.9	-1.4	10.7

Source: FAO Statistics (1999)

strongest growth occurred in the cheese and whey import markets, where growth on average was 7 and 10.7 percent respectively (Table 2-9).

Imports of dry milk were down significantly in 1998 (57,086 metric tons) when compared to imports in 1997 (73,697 metric tons). Since 1991 imports of dry milk has been decreasing by 1.4 percent per year, and for the period 1981 to 1990, imports decrease by 2 percent per year. With the exception of dry milk, dairy imports into Japan have been strong (Table 2-9). Given Japan's high degree of self-sufficiency in butter, imports are relatively insignificant.

Imports of dairy products into Japan have been regulated since the 1960s. Butter, milk powders, and whey powder have been subject to state trading by the Livestock Industry Promotion Corporation (LIPC) and import quotas since 1966. Cheese has been subject to import quotas as well. In 1989, all import quotas on cheese were converted to tariff rate quotas and with the UR GATT agreement in 1994, all dairy import quotas were converted to tariff rate quotas as well. However, state trading in dairy products still remains in the non-fat dry milk and butter import markets (GATT, 1992, 1995; WTO, 1998b).

Japan does not belong to any bilateral or regional trade agreements. All tariffs rates are applied equally to all countries. Prior to the UR GATT, all import quotas were applied globally. (GATT, 1995).

As part of its commitment to the WTO, Japan has established a TRQ quota limit of 3,000 tons for whey that will increase to 4,500 tons by the year 2,000. Also tariff rates on pizza cheese will be reduced by 35 percent and tariff rates on grated cheese will be reduced by 25 percent (USDA-FAS, 1998b).

The average tariff peak levied on dairy products in Japan is 158 percent. Tariffs peaks range from 370 percent for yogurt to 30 percent for cheese. Milk tariffs in Japan are of the highest the world, second only to Canada.

Given the growth in consumption and the decrease in self-sufficiency, Japan will likely become an even larger importer of dairy products. Although Australia and New Zealand are predicted to be the primary beneficiaries of freer trade in Japan, there are also opportunities for the US. Dobson (1997) suggest that in the Asian markets, opportunities to increase exports lie primarily in differentiated products such as cheese, ice creams and yogurts. In terms of bulk commodities, there are opportunities for the U.S. in the whey market because the U.S. has dominated this market, where the U.S. market share of whey imports into Japan has been as much as 60 percent and is currently 40 percent.

Mexico

Mexico is one of the largest importers of dairy products in the world, and because of the relative close proximity to the U.S., it is also one of the largest importers of U.S. fluid milk and dairy products. With the exception of the cheese import market, Mexico consistently ranks among the top ten importing countries of dairy products and has been as high as the second largest importer of non-fat dry milk in 1997 (FAO Statistics, 1999). In 1998, Mexico's share of world dairy imports was 3.26 percent, this was down from 1997 by .19 percent.

Like many of the East Asian countries, the consumption of dairy products in Mexico is growing faster than domestic production. The primary market is Mexico City, which is less than 1000 miles from dairy markets in the Southwest U.S. This provides the U.S. with transportation cost advantages that can not be duplicated by any other country (USDEC, 1997b).

Table 2-10 Per-capita consumption of dairy products in Mexico: 1961-1997

Year	*All Milk**	*Butter*	*Cheese*	*Skim Milk**	*Whole Milk**	*Whey**
			Kilograms			
1961	70.47	0.29	1.57	7.14	69.93	6.54
1965	63.38	0.32	1.47	8.23	62.47	6.28
1970	90.31	0.43	1.55	15.23	82.79	6.58
1975	110.86	0.44	1.52	9.61	109.87	6.52
1980	147.24	0.68	1.47	9.75	144.50	6.66
1985	131.01	0.67	1.38	36.42	100.36	5.93
1990	117.17	0.78	1.50	13.75	109.47	7.35
1991	99.12	0.74	1.52	15.61	85.52	7.92
1992	117.54	0.90	1.77	13.16	108.69	10.50
1993	124.99	0.85	1.83	12.75	114.51	10.37
1994	115.02	0.74	1.92	15.16	99.96	11.65
1995	106.16	0.56	1.56	10.76	98.79	10.36
1996	107.03	0.50	1.55	15.07	96.28	13.43
1997	111.24	0.61	1.65	23.91	90.70	13.62
Average Annual Growth			*Percent*			
1961-70	3.23	4.54	-0.06	10.32	2.37	0.12
1971-80	5.35	5.32	-0.54	1.40	6.11	0.15
1981-90	-1.93	1.79	0.47	44.49	-1.70	1.28
1991-97	-0.20	-2.19	1.83	11.90	-1.66	10.19

*Include food and other uses, such as cattle feed.
Source: FAO Statistics (1999)

Mexico's consumption per-capita in all milk products has been declining for the last two decades. For the period 1981 to 1990, per-capita consumption decreased on average by nearly 2 percent and from 1991 to 1997, per-capita consumption decreased on average by .2 percent annually. Of all dairy products, growth in per-capita consumption in skim milk and whey has been of the strongest. For the period 1991 to 1997, per-capita consumption for skim milk and whey grew on average by 12 and 10 percent per year respectively. Also, per-capita consumption in these products reached record high's of 23.91 kg for skim milk and 13.6 kg for whey in 1997 (Table 2-10). The decline in per capita milk consumption this decade is attributed to the devaluation of the peso and high inflation, which resulted in imports being more expensive. As the economy recovers and per-capita income reaches pre-devaluation levels, per capita consumption in dairy products is expected to rise (USDEC, 1997b).

Imports of dairy products into Mexico have been overall increasing this decade. Since 1991, imports have been increasing by 5.6 percent per year on average. Average annual growth from 1991 to 1998 in butter, cheese, dry milk, and whey has been 3.4, 23, 10, and 27 percent respectively. The strongest growth in dairy imports into Mexico occurred from 1971 to 1980. During this decade, total imports of dairy products increased by nearly 40 percent per year on average. The strongest growth for individual products occurred in the dry milk import market. Dry milk imports grew by 47 percent per year on average (Table 2-11).

Currently, Mexico's production is about 80 percent of total consumption, but by the year 2005, Mexico's self-sufficiency is projected to fall to 73 percent. This is primarily because the growth in production per capita is significantly less than the growth in consumption per capita (USDEC, 1997b).

Mexico's market access commitment to the UR GATT resulted in the tariffication of all dairy products. In 1996, the average tariff levied on all dairy products was 40.3 percent and the range was 0 to 128 percent. By the end of the

Table 2-11 Mexico dairy imports: 1961-1998

Year	*Milk Equivalent*	*Butter*	*Cheese*	*Dry Milk*	*Whey*
			Metric Tons		
1961	126,102	8	145	12,867	-----
1965	134,283	13	174	15,583	-----
1970	336,683	3,549	822	35,791	-----
1975	229,484	3,051	1,341	20,888	-----
1980	2,141,557	25,154	2,426	237,412	3,700
1985	1,787,818	25,444	7,448	195,851	1,837
1990	2,726,226	27,108	10,362	308,154	13,526
1991	1,142,855	37,713	14,631	81,973	16,751
1992	2,450,155	39,668	22,225	236,362	31,923
1993	2,726,246	40,460	29,506	260,547	20,931
1994	2,289,942	35,947	40,143	186,570	30,451
1995	1,689,224	20,072	16,397	156,131	25,178
1996	1,912,993	18,529	20,653	158,925	48,636
1997	2,121,080	24,793	26,078	174,381	49,174
1998	2,021,171	27,325	33,816	149,552	56,642
Average Annual Growth			*Percent*		
1961-70	16.1	-----	40.2	16.7	-----
1971-80	39.7	39.1	23.4	47.3	-----
1981-90	6.1	3.6	31.3	7.1	64.5
1991-98	5.6	3.4	23.1	9.7	27.2

Source: FAO Statistics (1999)

GATT implementation period the average will be 57.8 percent and the range will be 18 to 125.1. In the past, dairy products were imported under a licensing system where licenses were rejected if supplies were sufficient domestically (GATT, 1993).

Prior to the UR GATT, state trading in dairy products existed in Mexico to some degree. Currently, state trading still exists in the powdered milk market where the company CONASUPO is the sole purchaser of milk powder. This publicly regulated company imports milk powders under NAFTA and WTO regulations and sells to industrial users by public auction where a floor price is set. In addition to importing, CONASUPO also does storage and distribution (WTO, 1997; GATT, 1993).

Since NAFTA, Mexico has established preferential tariff rates for U.S. dairy products. When NAFTA went into effect, a maximum of 45,000 metric tons of U.S. milk powder could enter Mexico duty free. This quantity was set to expand by 3 percent per year compounded annually. U.S. imports above the quota are assessed a tariff rate of no less than 139 percent. U.S. exports of fresh and processed cheese were assessed initial tariffs of 40 and 20 percent respectively. Both of these tariffs are to be reduced to zero by the year 2004 (FAS-USDA, 1998c). Overall tariffs rate assessed to other countries are typically twice the rate assessed to U.S. dairy products. However, the tariff rate for fresh and processed cheese for other countries is 125 percent, which is a 105 percent difference for processed cheese and a 85 percent difference for fresh cheese.

In summary, the future of dairy imports in Hong Kong, Japan and Mexico is positive. In each of these countries recent growth in the per capita consumption of individual dairy product has been strong and is far exceeding the growth in per capita production. Growth in total milk imports has averaged this recent decade 14.2, 2.7, and 5.7 percent for Hong Kong, Japan, and Mexico, respectively. As Japan and

Mexico recover from economic crisis and instability and as these countries further deregulate their dairy industries, additional increases in consumption and import growth are expected.

The outlook for U.S. dairy exports appears positive. As the EU reduces export subsidies and market share is loss, the US is in a good position to gain greater access to international markets. Although Australia and New Zealand are expected to be the primary gainers from the new trade environment, unlike these countries, the U.S. has the production capacity to be a major world supplier.

CHAPTER 3
PRODUCTION THEORY APPROACH TO INTERNATIONAL TRADE

An objective of this study is to utilize production theory as a means of obtaining derived demand equations for imported dairy products into selected countries considered to be potential target markets for the United States. In past studies, imports are considered to be final goods that enter directly into the consumer's utility function and the resulting demand equations for imports are derived from consumer maximization theory. However, given the nature of international trade, where traded goods are either used in other production processes or go through a number of domestic channels before reaching the consumer, it is more appropriate to view imported goods as intermediate products than as final consumption goods even if no transformation takes place.

The primary objective of this chapter is to develop the differential approach to the theory of the firm and to present the methodology of how it will be applied to the demand for imported dairy products. However, before presenting this approach and its application, the justification for using production theory to model import demand is further explored.

Justification of the Production Approach to International Trade

The application of production theory to international trade is by no means a new concept. Past research that used a production theory approach to international trade include Burgess (1974a) and (1974b), Kohli (1978) and (1991), Diewert and Morrison (1989), and Truett and Truett (1998). However, these studies used production theory to estimate aggregate import demand and not the import demand for individual products or similar products from different sources. Each of these studies acknowledged that most goods entering into international trade require further processing before final demand delivery. They further acknowledged that even when a traded product is not physically altered, activities such as handling, insurance, transportation, storing, repackaging, and retailing still occur. This results in a significant amount of domestic value added when the final product reaches the consumer. Therefore it is more appropriate to view imported products as inputs rather than as final goods even if goods are not transformed before they reach the consumer (Kohli, 1978; Diewert & Morrison, 1989).

The assumption of import decisions being made by profit maximizing firms and not by utility maximizing consumers has a number of advantages. One clear advantage is the correctness of this assumption in terms of how products are traded. Firms make import purchases and rarely do consumers purchase products directly from other countries. Another advantage relates to how traded products are typically reported. Traded commodities are typically reported in bulk quantities and values at dockside. Consumers almost never purchase commodities in such quantities or at the port.[1] Therefore, assuming that import decisions are made by a profit-maximizing firm is more consistent with how trade data is typically reported.

Kohli (1991) notes that viewing imports as intermediate goods not only has its merits in correctness, but it also leads to substantial simplifications theoretically. One simplification is that the demand for imports can be derived from production theory and there is no need to model final demand. Second this approach allows for the avoidance of the difficulties that arise when we aggregate over individual consumers. To expound on this point, data that are typically reported are usually aggregate data. Therefore, if we are estimating demand, we are estimating aggregate demand, and if we are estimating derived demand it is aggregate or industry derived demand. The differences between aggregate demand and aggregate derived demand is that one is an aggregation over consumers and the latter is an aggregation over firms. When we consider optimizing behavior by both consumers and firms, do the properties derived from consumer and producer-maximizing behavior hold in the aggregate? Mas-Colell et al. (1995) indicates that when consumer preferences and wealth effects are identical across consumers, the aggregate demand function satisfies all of the properties of an individual demand function.[2] However, if there is the slightest difference in preferences, and if these differences are independent across consumers, as one would expect, the property of symmetry, which is a common property tested in most empirical demand studies, will almost certainly not hold.[3]

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[1] Such is the case with United Nations trade data that is reported by customs in each individual country.

[2] The properties of a system of demand equations for a utility maximizing consumer are adding up, homogeneity, and the symmetry and negative semi-definiteness of the matrix of price effects.

When we aggregate across firms, there are no such conditions required for the properties of optimal firm behavior to hold in aggregation. This is because the aggregate profit obtained by each production unit maximizing profit separately, taking prices as given, is the same as that which would be obtained if they were to coordinate their actions in a joint profit maximizing decision (Mas-Colell et al., 1995)[4]. This result implies that the profit maximizing output arrived at if all firms coordinated their actions is the same as the sum of the individual output of each profit maximizing firm. It further implies that the total cost of production for the coordinated output is the same as the sum of total cost for each individual firm if firms are price takers in the input market (Mas-Colell et al., 1995). Therefore if we estimate input demand functions and output supply functions using aggregate data, the properties of the demand and supply functions for each individual firm will theoretically hold in aggregation.[5]

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[3] The property of negative semi-definiteness holds in aggregation under less strict conditions. If each individual demand function satisfies the uncompensated law of demand then the aggregate demand function satisfies the week axiom of reveal preference which implies a negative semi-definite price effect matrix.

[4] Prices are assumed as given even with coordination.

[5] The properties of the input demand function are the same as the properties of the consumer demand function. Each of these is described in the next section. The properties of the supply function are that the matrix of price effects is symmetric and

The Differential Approach to the Theory of the Firm

The differential approach to the theory of the firm is comparable to the differential approach to consumer theory proposed by Henri Theil in 1965 and A.P. Barten in 1966. The empirical application of the differential approach to consumer demand resulted in the Rotterdam model, which has been used extensively in demand studies and to a lesser extent in import demand studies. The majority of import demand studies that used the Rotterdam model assumed that imported goods entered directly into the consumer's utility function and strong assumptions were made about how consumers view imported and domestic goods and how they grouped commodities. Furthermore, it was often assumed that these commodity groups were to some degree independent in terms of the consumer's utility function (For example, see Lee, Seale, and Jierwiriyapant, 1990; Seale, Sparks, and Buxton, 1992; and Zhang, Fletcher, and Carley, 1994.). In these studies, the intermediate nature of imports was not considered.

In comparing the two differential approaches (consumption and production) to the demand for imports, advantages of the production approach become evident. First, in the production approach we need not assume that consumers view imports as separate from domestic goods. Furthermore, we need not assume that consumers group goods such that there is no good that belongs to two different groups and that those groups are separable. Instead we only need to make assumptions about the

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positive semidefinite. The author assumed that firms are still price takers even with coordination. Production technology can vary over firms.

production possibilities of the firm in question and the input requirement set for a given production possibility set, which may be easier to argue intuitively.

Second, as mentioned before, optimization properties of the firm theoretically hold in aggregation while these same properties will more than likely not hold when we aggregate over consumers. Therefore, imposing economic restrictions in the production case is more justified. The difficulties that arise when aggregating over consumers are rooted in the ordinal nature of the utility function. The value of a utility function for a given bundle of goods in and of itself is meaningless, it only has meaning when we compare it to the value of utility from another bundle. Therefore, if we aggregate across consumers, we are only concerned with the preserving of a rational preference ordering and not the aggregate value of the utility function. If there are differences in preferences across consumers then it is possible that aggregate data may violate the rationality assumptions yielding the properties of demand such as the weak axiom of reveal preference and transitivity (Mas-Colell et al., 1995). In contrast, the value of a production function is a physical quantity and in aggregation we get the aggregate quantity produced and as long as the individual firms are maximizing profits, this implies that the industry is operating at it's optimal potential.

In estimating consumer demand, an advantage of the differential approach is that a functional form of the consumer's utility function need not be assumed. Furthermore, economic properties resulting from consumer maximization can be both tested and/or imposed as well as further demand restrictions such as strong and weak separability of individual commodities, and depending on the final version chosen this approach results in a linear system of equations. There are similar advantages to the differential production approach as well. Comparable to the consumer approach, a particular functional form of the production function, profit function, or cost function need not be assumed. The maximization properties in consumer demand (homogeneity, symmetry, etc.) also apply in production theory. These properties can also be tested and/or imposed in the production approach. Lastly, following a similar process as the derivation of the Rotterdam model, the differential production approach results in a linear system of input demand and output supply equations.

Overview of Theory

In this chapter the multi-product firm is considered. This firm makes m products and utilizes n inputs in the production process. Letting $\boldsymbol{q} = [q_1, \ldots, q_m]$ represent the vector of m possible outputs and $\boldsymbol{x} = [x_1, \ldots, x_n]$ represent the vector of n inputs, the production of the firm is expressed implicitly as

$$h(\boldsymbol{q},\boldsymbol{x}) = 0. \tag{3.1}$$

Equation (3.1) is twice differentiable, continuous and is expressed such that $\partial h / \partial q_r < 0$ and $\partial h / \partial x_i > 0$ for all $r = 1, \ldots, m$ and for all $i = 1, \ldots, n$.[6] Without any loss in generality, we can conveniently use the output-homogeneous form of equation (3.1) which implies that this function satisfies

$$\sum_{r=1}^{m} \frac{\partial h}{\partial \log q_r} \equiv -1 \quad . \tag{3.2}$$

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[6] When a production function is expressed in the form of equation (3.1) it is often referred to as a transformation function (Varian, 1992). For the single output firm this would be $h(q,x) = h(x) - q = 0$.

Selecting equation (3.1) such that it satisfies (3.2) amounts to representing the firm's technology by a unique production function (Laitinen and Theil, 1977; Laitinen, 1980; Theil, 1987). Note that equation (3.2) is automatically satisfied when the firm produces a single output and the production function is expressed implicitly in the form of equation (3.1) (Laitinen, 1980). This is not the case for every multi-product production function.

The objective of the firm is to maximize profits or minimize cost subject to the technology represented by equation (3.1). In this study it is assumed that firms maximize profits in a two step procedure which involves both profit maximization and cost minimization. The two step procedure to profit maximization assumes that within the firm there are two managers, a production manager and an input manager. Given both input and output prices, the production manager decides on a profit-maximizing output mix and then informs the input manager of his decision. Next, the input manager having knowledge of the target output specified by the production manager acquires the inputs necessary to produce the target output such that costs are minimized (Laitinen, 1980; Theil, 1987). An alternative approach is to assume a direct or one step profit maximization procedure where there is one manager that chooses both outputs and inputs simultaneously, given input and output prices. Due to the duality of cost and profit, it can be shown that the resulting system of input demand equations from each procedure are equivalent (Mas-Colell et al., 1995). This is because profit maximization implies cost minimization at some optimal output level.

Although these two procedures yield equivalent input demand equations, there are advantages to assuming the two step procedure. The direct profit maximizing procedure yields a system of input demand and output supply equations for the firm both expressed in terms of output and input prices. As a result of this procedure, the error terms in the supply and demand equations are statistically dependent (Laitinen, 1980; Theil, 1987). Therefore if the interest is in derived demand equations only, as with this study, the estimation of input demand without the supply equations can not be justified. However, the two step procedure results in supply and demand equations where the errors of the supply equations are independent of the errors in the input demand equations. In this case input demand can be estimated independent of supply (Laitinen, 1980; Theil, 1987). A second advantage of the two step procedure is that, if one is only concerned about input demand, this procedure only requires that firms are price takers in the input market, but the output market can be perfectly competitive, monopolistic, etc. (Mas-Colell et al., 1995). In the one step profit-max approach, both the output and input markets must be perfectly competitive, which may not always be the case. For example in Mexico, milk powders are imported by a state trader that purchases imports and resells these imports to firms in a public auction where a minimum price is set by the state trader (World Trade Organization (WTO), 1997). In this instance the assumption of a perfectly competitive output market is violated, but the assumption of a perfectly competitive input market still holds as long as the state trader is unable to influence input prices. The cost minimization problem is still valid because no assumption about the output market is necessarily needed. Further, Laitinen (1980) indicates that the resulting parameters of the one step approach are more difficult to interpret when compared to the two step procedure. Lastly, if the interest is in input demand alone, the two step approach allows us to proceed directly to the cost minimization problem. With this said, a brief overview of the cost minimization problem is needed before moving forward.

The cost minimization problem can be stated as the minimization of $\boldsymbol{w}'\boldsymbol{x}$ subject to the production function in equation (3.1), where $\boldsymbol{w} = [w_1,\ldots, w_n]$ is the vector of input prices and $\boldsymbol{x}$ is the vector of inputs previously specified. The first order condition of this problem expressed in matrix notation is

$$\boldsymbol{w} = \lambda \nabla_x h(\boldsymbol{q},\boldsymbol{x}). \tag{3.3}$$

λ is the lagrangian multiplier or marginal cost and ∇ is the matrix differential operator. It can be shown from equation (3.3) that the marginal rate of substitution between any two inputs (x_i and x_j) is equal to the input price ratio, w_i / w_j (Varian, 1992). This optimization procedure results in an optimal input mix that is a function of input prices and output.

The optimized value of the cost minimization problem is given by the cost function $c(\boldsymbol{w},\boldsymbol{q})$ where the corresponding conditional input demand functions are specified as $\boldsymbol{x}(\boldsymbol{w},\boldsymbol{q})$ (Mas-Colell, 1995; Varian, 1992). If we assume a production possibility set that is closed and satisfy the free disposal property, then the optimized cost and conditional demand functions have the following properties (Mas-Colell, 1995):

1. $c(\boldsymbol{w},\boldsymbol{q})$ is homogeneous of degree one in $\boldsymbol{w}$ and non-decreasing in $\boldsymbol{q}$ ($c(t\boldsymbol{w},\boldsymbol{q})=tc(\boldsymbol{w},\boldsymbol{q})$ and $\partial c/\partial q_r \geq 0$ for all r).
2. $c(\boldsymbol{w},\boldsymbol{q})$ is a concave function of $\boldsymbol{w}$.

3. $x(w,q)$ is homogeneous of degree zero in w ($x(tw,q)=x(w,q)$).
4. If $x(w,q)$ is singled valued then $\nabla_w c(w,q)= x(w,q)$ (Shepard's Lemma).
5. The matrix $\nabla_w x(w,q) = \nabla^2{}_w c(w,q)$ is a symmetric and negative semidefinite matrix.

Properties 1 and 3 indicate that if all input prices increased proportionally, the optimizing input bundle will remain unchanged and the overall cost of that bundle will increase in equal proportion. The intuition of these two properties is that only relative price changes effect the optimizing input bundle selected by the firm. Property 1 also indicates that it is not possible for output to increase while at the same time cost decreases (Chambers, 1988). Property 2 is the result of $c(w,q)$ being a function that represents the minimal cost given output quantities and input prices. The concavity of $c(w,q)$ suggest that if a firm chose an input bundle for a given vector of prices and then prices changed and the firm chooses a new optimal bundle, the cost of the new optimal input bundle will always be either less than or equal to the cost of the old input bundle at the new prices (Chambers, 1988). Geometrically, this also says that a line drawn tangent to the cost function is always above or on the curve. Property 4 states that the derivative of the cost function with respect to the *ith* input price results in the input demand equation for the *ith* input. This property is referred to as Shepard's Lemma. Property 5 is the result of $c(w,q)$ being concave and twice differential. We know mathematically that the hessian of a concave function results in a matrix that is symmetric and negative semidefinite (Mas-Colell, 1995). The Hessian of $c(w,q)$ being negative semidefinite translates into the matrix of own price effects being negative semidefinite resulting in demand equations with negative own-price effects, which is to be expected. The symmetry property suggests that $\partial x_j/\partial w_i = \partial x_i/\partial w_j$, which is a mechanical result from $c(\boldsymbol{w},\boldsymbol{q})$ being twice differentiable and Young's Theorem (Chambers, 1988). Each of these properties is a direct result of optimizing behavior by the firm. If any of these do not hold one can assume that the represented firm is not minimizing cost.

The derived demand equations resulting from the differential approach allows for the testing, imposing, and/or checking for each of these properties. Since we are assuming that firms exhibit optimal behavior we would expect for these properties to hold empirically.

The Differential Production Model

The differential production approach is comparable to the differential approach to the consumer. As mention, if we assume a cost minimizing firm that is subject to the technology given by equation (3.1), the result is a vector of input demand quantities that are a function of output and input prices expressed in general form as $\boldsymbol{x} = \boldsymbol{x}(\boldsymbol{q},\boldsymbol{w})$. The basis of the differential approach is the total differentiation of the general input demand equation. However, before moving forward, a number of concepts resulting from the cost minimization problem must be defined (Laitinen, 1980; Theil, 1987; Laitinen & Theil, 1977).

The first concept to be considered is the elasticity of scale. The elasticity of scale is defined as the proportion by which output changes when all inputs change proportionately which is equal to $\sum_i \partial h/\partial \log x_i$ for the multiproduct firm. However, if we consider the total differential of equation (3.1) in logarithmic form

$$\sum_{i=1}^{n} \frac{\partial h}{\partial \log x_i} d(\log x_i) + \sum_{r=1}^{m} \frac{\partial h}{\partial \log q_r} d(\log q_r) = 0, \tag{3.4}$$

and the result in equation (3.2), the elasticity of scale can be expressed as

$$\sum_{i=1}^{n} \frac{\partial h}{\partial \log x_i} = \sum_{i=1}^{n} \frac{w_i x_i}{\lambda} = \frac{C}{\lambda}.^{7} \tag{3.5}$$

For convenience, we define the reciprocal of the elasticity of scale as $\gamma = \lambda/C$ where C is the total cost, $\boldsymbol{w'x}$. In addition to being the reciprocal of the elasticity of scale, γ is also equal to the elasticity of cost with respect to a proportionate output increase defined as

$$\gamma = \sum_{r=1}^{m} \frac{\partial \log C}{\partial \log q_r}. \tag{3.6}$$

This is verified in Laitinen (1980, pp. 33-34).

The next concepts to be defined are the factor and product shares. If we again define total cost as C, the factor share is defined as

$$f_i = \frac{w_i x_i}{C}. \tag{3.7}$$

Note that $f_i > 0$ and $\Sigma f_i = 1$. Using the first order condition presented in Appendix A, equation (A.3a), it can be shown that

$$f_i = \gamma \frac{\partial h}{\partial \log x_i} \tag{3.8}$$

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[7] Given that we are only concerned with proportional changes in input and output, $d(\log x_i)$ and $d(\log q_r)$ can be placed before the summation signs. This result also makes use of the first order condition (A.3a) (Appendix A).

at the optimum. If we view $q_r(\partial C/\partial q_r)$ as the dollar value of the *rth* output evaluated at its marginal cost and $\Sigma_r\, q_r(\partial C/\partial q_r)$ as "total marginal cost", then the share of the *rth* product in total marginal cost is defined as

$$g_r = \frac{q_r(\partial C/\partial q_r)}{\sum_{s=1}^{m} q_s(\partial C/\partial q_s)}. \tag{3.9}$$

By totally differentiating the factor share equation we can define the Divisia indexes. Total differentiation of the factor share equation (3.7) is $df_i = (x_i / C)dw_i + (w_i / C)dx_i - (w_i x_i / C^2)dC$, which can also be expressed as

$$df_i = f_i d(\log w_i) + f_i d(\log x_i) - f_i d(\log C)\ . \tag{3.10}$$

If we sum equation (3.10) over *i*, we obtain

$$d(\log C) = d(\log W) + d(\log X) \tag{3.11}$$

Equation (3.11) is the Divisia decomposition of a logarithmic change in cost into the Divisia input price index and the Divisia input volume index, which are respectively defined as

$$d(\log W) = \sum_{i=1}^{n} f_i d(\log w_i) \tag{3.12a}$$

$$d(\log X) = \sum_{i=1}^{n} f_i d(\log x_i)\,. \tag{3.12b}$$

We can also define an implied Divisia volume index of the outputs as

$$d(\log Q) = \sum_{r=1}^{m} g_r d(\log q_r). \tag{3.13}$$

Lastly, we define the marginal share of the *ith* input in the marginal cost of the *rth* product as

$$\theta_i^r = \frac{\partial(w_i x_i)/\partial q_r}{\partial C/\partial q_r}, \tag{3.14}$$

and the Divisia mean of equation (3.14) as

$$\theta_i = \sum_{r=1}^{m} g_r \theta_i^r = \frac{1}{\lambda}\sum_{r=1}^{m} \frac{\partial(w_i x_i)}{\partial \log q_r}. \tag{3.15}$$

Equation (3.15) can also be regarded as the mean share of the *ith* input in the marginal cost of the firm.

As mention before, the basis of the differential production approach is the total differential of the general input demand equation resulting from the cost minimization problem. If we put the general input demand equation in matrix form, $\boldsymbol{x} = \boldsymbol{x}(\boldsymbol{q},\boldsymbol{w})$, the total differential is

$$d(\log \boldsymbol{x}) = \frac{\partial \log \boldsymbol{x}}{\partial \log \boldsymbol{q}'} d(\log \boldsymbol{q}) + \frac{\partial \log \boldsymbol{x}}{\partial \log \boldsymbol{w}'} d(\log \boldsymbol{w}). \tag{3.16}$$

If we premultiply equation (3.16) by $\boldsymbol{F}$ and use the results from the matrix equation in Appendix A (equation (A.20) and (A.22)) equation (3.16) becomes

$$\boldsymbol{F} d(\log \boldsymbol{x}) = \gamma \boldsymbol{K}\boldsymbol{G} d(\log \boldsymbol{q}) + \quad \psi(\boldsymbol{\Theta} - \boldsymbol{\theta}\boldsymbol{\theta}') d(\log \boldsymbol{w}).^{8} \tag{3.17}$$

Equation (3.17) is the system of input demand equations in their final form expressed in vector notation where the demand for the *ith* input is expressed as

$$f_i d(\log x_i) = \gamma \sum_{r=1}^{m} \theta_i^r g_r d(\log q_r) - \psi \sum_{j=1}^{n} (\theta_{ij} - \theta_i \theta_j) d(\log w_j). \tag{3.18}$$

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[8] $\boldsymbol{F}$ is a diagonal matrix where the factor shares, equation (3.7), are along the diagonal. $\boldsymbol{K}$ is an n×m matrix which has θ_i^r as its *(i,r)th* element. $\boldsymbol{G}$ is a diagonal matrix where the product shares, equation (3.9) are along the diagonal.

This equation describes the change in demand for the *ith* input, measured by the quantity component of the change in the *ith* factor share, in terms of output changes and input price changes.

In addition to equation (3.18), we can also define the input allocation decision which is comparable to the allocation equation for the consumer. If we sum equation (3.18) over *i*, this results in the following equation

$$d(\log X) = \gamma d(\log Q). \tag{3.19}$$

Equation (3.19) is the total input decision of the multiproduct firm, which says that the Divisia volume index of the inputs is proportional to the Divisia volume index of the outputs. Substituting equation (3.19) into equation (3.18) results in the input allocation decision

$$\begin{aligned} f_i d(\log x_i) = \theta_i d(\log X) + \gamma \sum_{r=1}^{m} g_r (\theta_i^r - \theta_i) d(\log q_r) \\ - \psi \sum_{j=1}^{n} (\theta_{ij} - \theta_i \theta_j) d(\log w_j). \end{aligned} \tag{3.20}$$

Equation (3.20) indicates that changes in the decision to purchase the *ith* input is dependent upon the changes in the total amount of inputs obtained, changes in output, and changes in input prices. Equation (3.19) and (3.20) can be parameterized such that they are linear in estimation and the resulting parameters can be restricted such that economic properties can be tested. The parameterization of these equations and the testing of economic properties will be discussed in detail in the next chapter.

Equation (3.19) or (3.20) also result in the following elasticities: The elasticity of the *ith* input with respect to the *rth* output for (3.19) and (3.20) respectively

$$\varepsilon_{x,q} = \frac{d(\log x_i)}{d(\log q_r)} = \frac{\gamma \theta_i^r g_r}{f_i} \tag{3.21a}$$

$$\varepsilon_{xq} = \frac{d(\log x_i)}{d(\log q_r)} = \frac{\gamma g_r (\theta_i^r - \theta_i)}{f_i}. \tag{3.21b}$$

The conditional own and cross price elasticity is

$$\varepsilon_{xw} = \frac{d(\log x_i)}{d(\log w_j)} = -\frac{\psi(\theta_{ij} - \theta_i \theta_j)}{f_i}. \tag{3.22}$$

The Divisia volume elasticity (equation (3.20) only) is

$$\varepsilon_{xX} = \frac{d(\log x_i)}{d(\log X)} = \frac{\theta_i}{f_i}. \tag{3.23}$$

In the primary references where the differential production approach is presented, the elasticities, equation (3.21a), (3.21b), and (3.22) are not discussed; however, equation (3.23) is. Also discussed in Laitinen (1980) is Allen's partial elasticity of substitution, which measures the substitution or complementary relationship between two inputs. This elasticity is equal to

$$\varepsilon_{xw}^{A} = \frac{d(\log x_i)}{d(\log w_j)} = -\frac{\psi(\theta_{ij} - \theta_i \theta_j)}{f_i f_j}, \quad i \neq j. \tag{3.24}$$

Equation (3.24) is sometime referred to as the Allen-Uzawa elasticities of substitution as a result of Uzawa (1962) discussion of them.

The information presented thus for is for an individual firm. If we want to apply this methodology to an industry we can simply sum the general demand equation across firms and proceed to derive the model from the general aggregate input demand function.

Application of the Differential Approach to the Derived Demand For Imported Dairy Products

In this study the import demand for dairy products differentiated by the source country of origin in selected international markets is assessed. Before describing how the differential production approach will be used to accomplish this objective, some assumptions must first be made.

The production approach to import demand assumes that all imported goods are intermediate goods that are used in production processes or that require a significant amount of value added before they reach the final consumer. This is particularly true for most imported dairy products. For example, skim milk powder, whole milk powder, butter oil and even butter are important inputs in a process called milk reconstitution, a technology that converts milk powder, milk fat products and other dairy products back into fluid milk for consumption or making other dairy products. Also whey and skim milk which are by-products of cheese and butter production respectfully, are used as ingredients in cattle feed and to some degree in infant formulas in countries like Mexico and Japan (Zhu et al., 1998). Although cheese is considered a final good, it is often a primary ingredient in non-dairy industries such fast-food restaurants. In the case of goods that are not transformed into other products such as ice cream, yogurt, and even some cheeses, these products are still purchased by firms and a significant amount of value added such as transportation, storage, etc. are embedded in these products before they reach the consumer. Therefore in the case of imported dairy products, the assumption that imported goods are intermediate goods and not final goods is more accurate.

Since the primary concern for this study is to assess the competitiveness of U.S. dairy products when compared to substitute products from other countries such as the EU and New Zealand, we must assume something about the nature of the substitution of similar products from different source countries. Following Armington's (1969) specification, similar imported dairy products such as EU cheese and US cheese are both individual goods that are part of the product group cheese, but different based on their source country of production. There are a number of reasons why similar products are viewed as different based on their source country of origin. Dairy products from different sources may actually be physically different. For example, the EU produces a larger variety of cheeses than the US. Therefore imports of cheese from the EU are likely to be different than cheese from the US. Other physical differences could be quality, protein and fat content, and taste. There may also be perceived differences, such as a country's reputation for a quality product, trade history, reliability and consistency, and political issues tied to trade (Zhou & Novakovic, 1996). The crux of this assumption is that within an importing country, a particular dairy product imported from a given source is considered a substitute for that same product from another source. However, because of the physical and perceived differences attributed the product due to its origin, these products are imperfect substitutes.

Given that we are assuming that firms import dairy products, we need to make assumptions about these firms. According to the United States Dairy Export Council (USDEC) a large percentage of the dairy products imported into Hong Kong, Japan and Mexico are imported by firms that primarily import products and then resell these products to other companies within the country. A primary characteristic of these firms is that they sell products to other firms in their original form. In this study it is assumed that dairy products are imported through this type of firm. Although, there are a number of firms within these countries that import products as well as transform these products into other products, it is assume that there is a separate entity within the firm that deals primarily with the procurement of imported dairy products. However, dairy imports through this type of entity make up the smaller percentage of imports in the importing countries. An example of this is in Mexico where Nestle is allowed to import dairy products that they use and sell. In addition to providing imported products to other firms, these firms also provide the services that are associated with importing. These services include, search and acquisition, transportation, logistics, and storing.

The advantage of assuming this type of firm is that the outputs and the inputs are one and the same. Therefore we need not be concerned about all the possible products that could result from these imported inputs or the technological advancements in milk reconstitution, whey production, and other dairy products production processes.

A major characteristic of this type of firm is that it deals primarily in imported goods. This assumption suggests that the procurement of imported goods by firms is a unique process separate from the procurement of similar products produced domestically. Even if the firm is a subsidiary or branch of a larger firm that purchases domestic and foreign produced inputs, it is not unlikely that the branch that is responsible for imported inputs deals primarily in this activity. This is because the acquisition of foreign produced goods is more involved than purchasing domestically produced goods.

If we assume a production function for these firms, then the output of these firms is the imported goods that are sold to other firms and the inputs are the imported goods from the various exporting countries. If we minimize cost subject to this function, the system of input demand equations resulting from the optimization procedure will be a system of import demand equations. If we assume product differentiation across source countries, then each import demand equation represents the demand for a product from a particular source.

In the importing countries, firms typically imported more than just dairy products. For example in Mexico, the company CONASUPO at one time imported dairy products as well as other food products (WTO, 1997). Therefore we must make assumptions about the relationship of the firm's various outputs and inputs. The firm that is assumed provides a number of physical outputs and services. The inputs required are the imported goods, labor and capital. Given that these firms do not transform the products they sell, the imported goods are clearly unique to the output that it is used for. For example if this firm sells imported US butter as a product, then the only input that could have made this product is butter from the US. Let us assume that in a given country, a firm imports beef and cheese from two sources, the US and the EU. The outputs of this firm would then be the services it provides, EU beef and EU cheese, and US beef and US cheese. In actuality, all inputs are independent of each other. The reason is labor cannot be substituted for the input EU beef in the production of EU beef, and nor can US beef be substituted for capital in the providing of services. Therefore each individual output has its own unique input. Theil (1975) referred to this relationship as input independence. In this case, the elasticity of output with respect to each input is independent of all other inputs, hence all cross price effects are zero. This further implies that the Hessian of the production function previously described is a diagonal matrix.

It is quite understandable that imported beef and cheese would be independent inputs; however, the independence of the inputs US cheese and EU cheese ignores the competition between these goods immediately after they leave the firm. In production processes these goods often compete as ingredients and in the wholesale and retail sector they compete for warehouse and self-space. They also compete to be part of consumers' diets. Although, it can be argued intuitively that similar imported goods from different sources are independent, to account for the substitution between goods immediately after they leave the firm, it is assumed that only the imported product groups such as butter, cheese, beef, etc. are independent. Further, it is also assumed that labor and capital, although not independent of each other are, independent of all other imported inputs. This is because labor and capital are unique to the services provided by these firms. This assumption is referred to as block independent inputs, and the production function can be written as

$$h(q,x) = h_1(q_1,x_1) + h_2(q_2,x_2) + \cdots + h_G(q_G,x_G)$$

where $\partial^2 h(q,x)/(\partial x_i \partial x_j) = 0$ and i and j represent two different input groups (Laitinen, 1980; Theil, 1987).

In addition to the block independence of inputs we can also assume independence in the individual outputs of these firms. The output independence assumption implies that no output is a specific substitute or complement of another. Although, we are already assuming that similar outputs such as the outputs US and EU cheese are substitutes in further production processes, it is perfectly logical that firms that purchase these outputs consider the product groups as independent. This suggest that firms within the country that purchased the outputs from the importing firms consider groups such as cheese, butter, beef, dry milk, etc. as independent of each other. In consumer theory, this type of an assumption indicated that consumers viewed these groups as independent in terms of utility. That is, the marginal utility gained from consuming butter given the marginal utility already gained from consuming cheese would be zero. However, in production this suggests that firms that purchased imported products from the importing firms do not consider groups as substitutable in their production processes. In the reconstitution of milk, firms use dry milk and butter. Although these firms may substitute dry milk from different sources and butter from different sources, they will not substitute butter for dry milk if there is a target consistency or set recipe for the final product.

When we assume that an output group is independent of another these output groups are block independent. This assumption means that the multi-product firm with the technology represented in equation (3.1) could be broken down into individual multi-product firms with a production function for each individual output group.

Utilizing the input independent and output independent assumptions, the differential input demand and allocation equations (equation (3.18) and (3.20)) have the same form

$$f_i d(\log x_i) = \gamma \sum_{r=1}^{m} \theta_i^r g_r d(\log q_r) - \psi \sum_{j=1}^{n} (\theta_{ij} - \theta_i \theta_j) d(\log w_j). \quad (3.25)$$

$$\begin{aligned} f_i d(\log x_i) &= \theta_i d(\log X) + \gamma \sum_{r=1}^{m} g_r (\theta_i^r - \theta_i) d(\log q_r) \\ &- \psi \sum_{j=1}^{n} (\theta_{ij} - \theta_i \theta_j) d(\log w_j) \end{aligned} \quad . \quad (3.26)$$

However, *m* is no longer the total number of outputs within the firm, but m is the total number of outputs within a given separable output group. *n* is no longer the total inputs required to produce all outputs, but only the inputs required to produce the goods within the output group. Take the group butter for example, $r = (1,\ldots..,m)$ would represent the different outputs of butter provided by these firms which would be U.S. butter, EU butter, New Zealand butter, Australia butter, and butter from other exporting sources and $i = (1,\ldots..,n)$ would be the input butter imported from the same source countries. All terms in equation (3.25) and (3.26) are defined as before except now they are group specific.

As mentioned previously, Laitinen (1980) suggest that the differential model be derived from a two-step profit maximization procedure which results in input demand equations statistically independent of output supply equations. In this research a two step approach is assumed. There is no information lost by not assuming a direct profit maximization procedure because the outputs and inputs of this type of firm are one in the same. If we were to derive input and output equations simultaneous from a direct profit-max procedure, this would result in a system of input demand equations exactly identical to the system of output supply equations.

Therefore, no extra information is gained from estimating output supply simultaneously with input demand.

In summary, equation (3.26) will be the equation that will be used to estimate the import demand for individual dairy products, which is the input allocation model. Estimation of this model provides the conditional own and cross price elasticities, the Allen-Uzawa elasticities of substitution, and the Divisia input index elasticity. In its present form, equation (3.26) also provides the elasticity of input with respect to output; however, given that inputs and outputs are one in the same, estimating this equation as is result in endogeneity problems. The procedure used to correct this problem is presented in the next chapter. The corrected allocation model no longer provides the output elasticity.

The assumptions that will be imposed are summarized as follows:

1. Imported dairy products are intermediate goods that are differentiated by the source country of production.
2. Imported dairy products are imported through importing firms or subsidiaries of major firms that deal primarily in imported dairy products.
3. Inputs and outputs are block independent such that we can separate the production function of the firm into individual production functions.
4. Firms maximize profits in a two step procedure where a production manager reports the output desired to the inputs manger, and the input manger minimizes the cost of producing that output.

Assumption 1 is the primary justification for using a production approach to model import demand. Assumption 2 allows for the estimation of import demand without including the domestic market. This is because if firms deal only in imported goods, with the exception of labor and capital, the inputs will be the imports used to make up the output. The resulting factor demand equations will be the imports demand equations and it is the output of these firms that compete with domestically produced dairy products. The independence assumptions allows for an individual product group (i.e. cheese from the various exporting sources) to be analyzed separate from all other groups. Lastly, because of the two step profit maximization procedure, this allows for the derivation of the differential factor demand model from cost minimization and we need not be concern with output supply.

CHAPTER 4
ECONOMETRIC ISSUES AND THE DIFFERENTIAL FACTOR DEMAND MODEL

Parameterization of the Differential Factor Allocation Model

The parameterization of the differential factor allocation model (DFAM) is comparable to the way in which the differential approach to consumer demand is parameterized. In the previous chapter, it was mention that equation (3.26) is the model chosen for estimation in this research; however, due to output and inputs being the same for the type of firm assumed, estimation of equation (3.26) results in endogeneity problems. This can be corrected by assuming that the outputs of the importing firm are not the imported products from the individual sources, but are the individual product groups. For example, this says that an importing firm imports cheese from the various exporting countries and provides the output "imported cheese". The imports from the different sources thus compete to be a part of the total output package. When we aggregate over firms, the total industry output is the total amount of cheese imported by that country. Assuming that importing firms provide the total packages, imported cheese, imported butter, and imported whey, greatly simplifies equation (3.26). With the added assumption of block independent input and outputs, where the output blocks are now treated as individual goods, this allows for the multi product production function to be treated as the sum of individual single product production functions. Recall that equation (3.26) was of the form

$$f_i d(\log x_i) = \theta_i d(\log X) + \gamma \sum_{r=1}^{m} g_r (\theta_i^r - \theta_i) d(\log q_r)$$
$$- \psi \sum_{j=1}^{n} (\theta_{ij} - \theta_i \theta_j) d(\log w_j). \tag{4.1}$$

If we assume that the total import group is now the output of the firm, equation (4.1) becomes

$$f_i d(\log x_i) = \theta_i d(\log X) - \sum_{j=1}^{n} \pi_{ij} d(\log w_j).^{[1]} \tag{4.2}$$

The simplification of equation (4.1) is the result of $\theta_i^r = \theta_i$. This is because when we have only one output, the marginal share of the *ith* input in the marginal cost of the *rth* product (θ_i^r) is also the Divisia mean (θ_i). The Divisia mean of the marginal share was defined in chapter 3 as

$$\theta_i = \sum_{r=1}^{m} g_r \theta_i^r . \tag{4.3}$$

Since we technically have only a single output, $g_r = 1$, since it is the share of the *rth* product in total marginal cost which is 1.0 or 100 percent in this case, and $r = 1$ since we have only one output. This results in $\theta_i^r = \theta_i$, and the second term on the right hand side of equation (4.1) vanishes.

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[1] $\pi_{ij} = \psi(\theta_{ij} - \theta_i \theta_j)$. θ_i is the marginal share of the *ith* input in marginal cost. As before, f_i is the *ith* factor share of total cost, x_i's are the inputs, $d(\log X)$ is the Divisia input index, and w_j's are the input prices.

We now proceed to parameterize equation (4.2). The DFAM describe the behavior of the firm in infinitesimal changes in the log of prices and quantities; however, observations of the firm do not yield infinitesimal changes. Therefore equation (4.2) must be reformulated in terms of discrete time or finite log changes. For example, $d(\log w) = dw/w$ is converted to $Dw_t = \log(w_t) - \log(w_{t-1})$. The same is done for $d(\log x_i)$. We also change the factor share f_i to the average factor share of two consecutive periods, t and $t-1$, $\bar{f}_{it} = (f_{it} + f_{it-1})/2$ (Laitinen, 1980; Theil & Laitinen, 1978). Lastly we assume the π's and θ's are constants. This has two purposes. First, this assumption makes the DFAM linear such that the π's and θ's are the parameters to be estimated, and second, this specification result in a contemporaneous covariance matrix of disturbances that are the same for each period (Laitinen, 1980).

Recall in Chapter 3 that the DFAM was derived from the differential factor demand model by using the relations, $d(\log X) = \gamma d(\log q)$, which says that the Divisia input index is equal to the reciprocal of the elasticity of scale (γ) times the derivative of the log of quantity. This equality may not exactly hold when converted to finite log changes. We therefore compute the residual quantity

$$E_t = DX_t - \bar{\gamma}_t Dq_t \,. \tag{4.4}$$

Laitinen (1980) showed that in the direct profit maximization approach $\gamma = R/C$, where R is total revenue and C is total cost. Through the relationship between profit maximization and cost minimization, he proposed that we use this relationship in place of $\gamma = \lambda/C$ since revenue is observable and the Lagrange multiplier is not. He further proposed that in the finite model we use $\bar{\gamma}_t = \sqrt{R_t R_{t-1}/C_t C_{t-1}}$, which is the geometric mean of γ in period t and t-1. The finite change version of the differential input demand model with the residual component accounted for is

$$\bar{f}_{it}(D\,x_{it} - E_t) = \theta_i(\bar{\gamma}D\,q_t) + \sum_{j=1}^{n} \pi_{ij}\ D\,w_{jt} + \varepsilon_{it}{}^{2}. \tag{4.5}$$

If we sum equation (4.5) over i we get

$$\textstyle\sum_i \bar{f}_{it}(D\,x_{it} - E_t) = DX_t - E_t = \bar{\gamma}D\,q_t\,. \tag{4.6}$$

Substituting equation (4.6) into equation (4.5) we get

$$\bar{f}_{it}D\,x_{it} = \theta_i(D\,X_t - E_t) + \sum_{j=1}^{n} \pi_{ij}\ D\,w_{jt} + \varepsilon_{it} \tag{4.7}$$

which is the finite change version of equation (4.2) with the residual component adjustment.

Laitinen (1980) also proposed that we define γ such that $E_t = 0$. This is accomplished by setting $\gamma_t = DX_t / Dq_t$. Although this specification is not advised when estimating equation (4.5), since γ is not in equation (4.7) this alternative poses no problem. Since we do not know the prices that these firms sell their imports for, we cannot get the total revenue in order to calculate $\gamma = R/C$. Furthermore, if the output market is not perfectly competitive, results from the profit-max approach are no longer interchangeable with cost minimization results. Therefore the second specification of γ is the one used in this study. Therefore we can rewrite equation (4.7) as

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[2] Note that equation (4.5) is the finite change version of the differential demand model equation (3.25), and not the allocation model, equation (3.26).

$$\bar{f}_{it} D\,x_{it} = \theta_i D\,X_t + \sum_{j=1}^{n} \pi_{ij}\, D\,w_{jt} + \tilde{\varepsilon}_{it} \tag{4.8}$$

where $\tilde{\varepsilon}_{it} = \varepsilon_{it} - \theta_i E_t$ and E_t.= 0. Equation (4.8) is the model that will be used to estimate the derived demand for imports, which we will call the differential factor allocation model (DFAM).

Estimation of the DFAM

To simplify the system of equations represented by (4.8), let $y_{it} = \bar{f}_{it} D\,x_{it}$, $X_i = [D\,X \;\; D\,w_{i1} \;\; D\,w_{i2} \;\; \cdots \;\; D\,w_{in}]$, and $\beta_i = [\theta_i \;\pi_{i1}\; \pi_{i2} \cdots \pi_{in}]'$. The resulting system of equations can be written as

$$\begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_n \end{bmatrix} = \begin{bmatrix} X_1 & 0 & 0 & 0 \\ 0 & X_2 & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & X_n \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdots \\ \beta_n \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \varepsilon_n \end{bmatrix} \tag{4.9}$$

$$Y = XB + \varepsilon \tag{4.10}$$

where each y_i is a $T \times 1$ vector (T indicates time), X_i is a $T \times (n+1)$ matrix of explanatory variables (n is the number of goods in the system which is also the number of equations), each β_i is a $(n+1) \times 1$ vector of parameters, and each ε_i is a $T \times 1$ error term vector.

The Ordinary Least Squares (OLS) estimator for each equation is

$$\hat{\beta}_i = (X_i' X_i)^{-1} X_i' y_i\,. \tag{4.11}$$

The parameter vector $\hat{\beta}_i$ requires the classical regression assumption $E[\varepsilon_i \varepsilon_i'] = \sigma_i^2\, I_T$ hold. The problem in estimating a system of equations using OLS is not of consistency but of efficiency (Greene, 1997). For OLS to be efficient $E[\varepsilon_i \varepsilon_j']$ must equal the empty set (*i* and *j* are the *ith* and *jth* equations). This would suggest that each equation in the system is independent. However for the DFAM, this clearly is not the case because the dependent variables of each equation are shares of total expenditures. This suggests that $E[\varepsilon_i \varepsilon_j']$ may not equal the empty set because the relationship in the dependent variables implies a relationship in the error term (Greene, 1997; Theil, 1971).

Estimation of the DFAM is a problem of Seemingly Unrelated Regressions (SUR). This is because the equations in the system are linked through the error term and would otherwise "seem unrelated". The first method discussed for estimating a SUR model is the joint Generalized Least Squares (GLS) estimation procedure. Recalling equation (4.9) and (4.10), the variance matrix for the system represented is

$$E[\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'] = \boldsymbol{V} = \Sigma \otimes \boldsymbol{I}_T, \tag{4.12}$$

where

$$\Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2n} \\ & \vdots & & \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nn} \end{bmatrix} \tag{4.13}$$

and $\boldsymbol{I}$ is the identity matrix of order T. This indicates that the least squares assumptions that the variance is constant over observations (homoskedastic) and that the errors are not correlated over observations are still valid. However, $E[\varepsilon_i \varepsilon_j]$ is no longer equal to $[\mathbf{0}]$ when i is not equal to j, but is equal to $\sigma_{ij}\boldsymbol{I}_t$. This requires the joint GLS estimator for equation (4.10), which is

$$\hat{\beta}_{GLS} = [X'V^{-1}X]^{-1}X'V^{-1}Y = [X'(\Sigma^{-1} \otimes I)X]^{-1}X'(\Sigma^{-1} \otimes I)Y \quad (4.14)$$

where the variance is

$$Var[\hat{\beta}_{GLS}] = [X'(V^{-1})X]^{-1} = [X'(\Sigma^{-1} \otimes I)X]^{-1} \quad (4.15)$$

(Zellner, 1962; Theil 1971). Zellner (1962) shows as a formal proof that equation (4.14) is a more efficient estimator than the single equation least squares estimator.

A feature of the DFAM model is that the X matrix is identical for each equation in the system. Therefore equation (4.10) can be written as

$$Y = (I_n \otimes X_1)B + \varepsilon. \quad (4.16)$$

The GLS estimator becomes

$$\begin{aligned} \hat{\beta}_{GLS} &= [(I \otimes X)'(\Sigma^{-1} \otimes I)(I \otimes X)]^{-1}(I \otimes X)'(\Sigma^{-1} \otimes I)Y \\ &= [\Sigma \otimes (X'X)^{-1}](I \otimes X')(\Sigma^{-1} \otimes I)Y \quad (4.17) \\ &= [I \otimes (X'X)^{-1}X']Y. \end{aligned}$$

When the matrix of explanatory variables are identical in each equation, the joint GLS estimator is the single equation OLS estimator. This indicates that there is no gain in efficiency when using GLS over OLS when the explanatory variables are identical (Theil, 1971). Such is the case for the unrestricted DFAM model.

A problem in using the GLS estimator is that Σ is usually unknown, making GLS impossible to use. However given that the single equation OLS estimator is a consistent estimator of the true parameter vector, the residuals could be used to construct consistently the elements of Σ (Zellner, 1962; Theil, 1971; Greene, 1997). Letting $e_j = y_j - X_j \hat{\beta}_j$, where e_j is the vector of residuals from the *jth* equation estimated using OLS, a consistent estimate of σ_{ij} is

$$s_{ij} = \frac{\boldsymbol{e}_i'\boldsymbol{e}_j}{\left[(T-n_i)(T-n_j)\right]^{1/2}}, \tag{4.18}$$

where

$$\boldsymbol{S} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ & \vdots & & \\ s_{n1} & s_{n2} & \cdots & s_{nn} \end{bmatrix}. \tag{4.19}$$

Using $\boldsymbol{S}$ for Σ, the joint Feasible GLS (FGLS) estimator is

$$\hat{\beta}_{FGLS} = [\boldsymbol{X}'(\boldsymbol{S}^{-1} \otimes \boldsymbol{I})\boldsymbol{X}]^{-1}\boldsymbol{X}'(\boldsymbol{S}^{-1} \otimes \boldsymbol{I})\boldsymbol{Y}. \tag{4.20}$$

Theil (1971) and Zellner (1962) indicate that for a sufficiently large number of observations, the FGLS estimator has approximately the same distribution as the GLS estimator and that

$$Var[\hat{\beta}_{FGLS}] = [\boldsymbol{X}'(\boldsymbol{S}^{-1} \otimes \boldsymbol{I})\boldsymbol{X}]^{-1} \tag{4.21}$$

is a consistent variance matrix. Zellner (1962) also proves that the FGLS estimator gains equally in efficiency as the GLS estimator when compared to OLS. Note that equation (4.20) also becomes the OLS estimator when the explanatory variables are identical in each equation.

Given that the matrix of explanatory variables is identical for each equation in the DFAM, one may ask "why even consider the GLS estimator?" The reason is that the GLS estimator allows for cross equational restrictions and hypothesis testing which is very important when testing the symmetry input demand property (Theil, 1971).

In estimating the DFAM using feasible GLS, an equation must be deleted from the system. This is because of the adding up condition, which leads to a singular covariance matrix. Therefore $\boldsymbol{S}^{-1}$ does not exist. This is corrected by deleting one equation from the system. However, resulting parameters may vary given the deleted equation (Barten, 1969).

Instead of using the OLS estimator to find a consistent estimator of Σ, an arbitrary vector $\boldsymbol{\beta}_o$ could have been used to construct a variance matrix Σ_o. Then Σ_o could then be used to estimate a new beta matrix $\boldsymbol{\beta}_1$ which could then be used to construct a new variance matrix. If we continue this process until $\beta_k - \beta_{k-1} = [0]$ or a vector of some small number, the resulting estimator is the iterative feasible GLS estimator. In large samples, iterative feasible GLS has no advantage over feasible GLS. Its' advantages in small samples is dependent on the data used. Also note that with the added assumption of normality, the iterative feasible GLS estimator becomes the Maximum Likelihood Estimator (Green, 1997)[3].

For convenience, let $y_{it} = \overline{w}_{it} D x_{it}$ and $f_{it}(\boldsymbol{\Theta}, \boldsymbol{X}) = \theta_i DX_t + \sum_{j=1}^{n} \pi_{ij} D w_{jt}$.

The DFAM becomes (expressed in terms of its disturbance component) $\varepsilon = \boldsymbol{Y} - f(\boldsymbol{\Theta}, \boldsymbol{X})$. Maximum Likelihood Estimation (MLE) begins with an assumption about the distribution of equation (4.10). Most often equation (4.10) is assumed normally distributed, although this need not always be the case. Assuming normality, the joint log likelihood function of the DFAM is (Barten, 1969; Harvey, 1993)

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[3] This particularly applies when the model is unrestricted. In such cases the MLE, GLS, and OLS are the same. The assumption of normality is simply using T in the denominator of equation (4.15) instead of the denominator corrected for degrees of freedom.

$$\begin{aligned}\ln L(Y) &= \frac{1}{2}T(n-1)\ln 2\pi - \frac{1}{2}T\ln|V| \\ &-\frac{1}{2}(Y - f(\Theta,X))'V^{-1}(Y - f(\Theta,X)).\end{aligned} \tag{4.22}$$

Note that as in the GLS case, an equation must be deleted from the system; however, unlike GLS, Barten (1969) shows that parameter estimates are invariant to the deleted equation when using MLE.

It can be shown that by taking the total differential of equation (4.22) the ML estimate of V is

$$\hat{V} = [\frac{1}{T}(Y - f(\Theta,X))'(Y - f(\Theta,X))] \otimes I = \frac{1}{T}\varepsilon'\varepsilon \otimes \mathrm{I}. \tag{4.23}$$

Substituting $\hat{V}$ *for* V in equation (4.22), it becomes the concentrated log likelihood function,

$$\ln L^* = -\frac{1}{2}T(n-1)(1+\ln 2\pi) - \frac{1}{2}T\ln|\hat{V}|. \tag{4.24}$$

The ML estimate of Θ is obtained by minimizing equation (4.24) with respect to the parameter vector. From vector differentiation,

$$\begin{aligned}\frac{\partial \ln L^*}{\partial\Theta} &= -\frac{T}{2}\frac{\partial \ln|\hat{V}|}{\partial\hat{V}}\frac{\partial\hat{V}}{\partial\Theta} \\ &= -\frac{T}{2}\hat{V}^{-1}\left[\frac{\partial(Y'Y - Y'f(\Theta,X) - f(\Theta,X)'Y + f(\Theta,X)'f(\Theta,X))}{\partial\Theta}\right]\frac{1}{T}\end{aligned} \tag{4.25}$$

which simplifies to

$$\frac{\partial \ln L^*}{\partial\Theta} = \hat{V}^{-1}\,[Y'X - \Theta X'X]. \tag{4.26}$$

Setting equation (4.26) equal to 0 and solving for Θ yields,

$$\Theta = (X'X)^{-1}X'Y, \tag{4.27}$$

which is the OLS single equation estimator. This shows that the unconstrained ML estimator for the DFAM is the OLS single equation estimator (Barten, 1969).

For the purpose of testing and imposing economic theory (particularly symmetry), ML numerical optimization techniques such as the Newton-Raphson method, the method of scoring, and the multivariate Gauss-Newton method can be used.

The Newton-Raphson iteration equation for the log-likelihood function may be written as

$$\Theta_{new} = \Theta_{old} - [D^2 \ln L(\varepsilon)]^{-1} D \ln L(\varepsilon). \tag{4.28}$$

The second term in equation (4.28) is the inverse of the Hessian of the log-likelihood function multiplied by the gradient of the log-likelihood function (Harvey, 1993). The Hessian of the log-likelihood function in the DFAM model is

$$D^2 \ln L(\varepsilon) = \begin{bmatrix} \dfrac{\partial^2 L}{\partial \Theta^2} & \dfrac{\partial^2 L}{\partial \Theta \partial V} \\ \dfrac{\partial^2 L}{\partial V \partial \Theta} & \dfrac{\partial^2 L}{\partial V^2} \end{bmatrix} = \begin{bmatrix} \dfrac{\partial^2 f}{\partial \Theta^2} V^{-1}\varepsilon - \dfrac{\partial f'}{\partial \Theta} V^{-1} \dfrac{\partial f}{\partial \Theta} & -\dfrac{\partial f'}{\partial \Theta}(V^{-1})^2 \varepsilon \\ -\dfrac{\partial f'}{\partial \Theta}(V^{-1})^2 \varepsilon & \dfrac{n}{2}(V^{-1})^2 - \varepsilon'(V^{-1})^3 \varepsilon \end{bmatrix}. \tag{4.29}$$

This iteration process is similar to iterative FGLS in that $[D^2 \ln L(\varepsilon)]^{-1} \times [D \ln L(\varepsilon)]$ is evaluated at Θ_{old} and then added to Θ_{old} to get Θ_{new}. Θ_{new} becomes Θ_{old}, and the process is repeated until convergence ($\Theta_{old} - \Theta_{new} = [0]$).

Rather than working with the inverse of the Hessian, it is sometimes more efficient to use its expectations. Taking the expectation of the Hessian and multiplying it by a minus 1 yields the information matrix

$$I(\varepsilon) = -E[D^2 \ln L(\varepsilon)] = \begin{bmatrix} \frac{\partial f'}{\partial \Theta} \hat{V}^{-1} \frac{\partial f}{\partial \Theta} & 0 \\ 0 & \frac{n}{2}(\hat{V}^{-1})^2 \end{bmatrix}.^{4} \tag{4.30}$$

The iteration equation becomes

$$\Theta_{new} = \Theta_{old} + I(\varepsilon)^{-1} D \ln L(\varepsilon). \tag{4.31}$$

If we iterate as before, this process is called the method of scoring.

In many applications the Information matrix is much easier to compute. Although convergence using the method of scoring may require more iterations than the Newton-Raphson method, each iteration will be performed more quickly. Furthermore, unlike the Hessian, the information matrix will always be positive definite (Harvey, 1993).

Due to concentration of the log-likelihood function, we need only use the upper left element of the information matrix for the convergence equation. The iteration equation becomes

$$\Theta_{new} = \Theta_{old} + \left[\frac{\partial f'}{\partial \Theta} \hat{V}^{-1} \frac{\partial f}{\partial \Theta} \right]^{-1} D \ln L(\varepsilon). \tag{4.32}$$

If we iterate as before, this procedure is referred to as the multivariate Gauss-Newton method (Harvey, 1993).

For each of these iterative procedures, the variance matrix for Θ is

$$Var[\Theta] = \left[\frac{\partial f'}{\partial \Theta} \hat{V}^{-1} \frac{\partial f}{\partial \Theta} \right]^{-1}. \tag{4.33}$$

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[4] Note that E(ε)=0 and that **V** is replaced with $\hat{\mathbf{V}}$.

For the unrestricted DFAM, there is clearly no advantage of MLE over GLS or OLS because each of these estimators is the same. However, when restrictions across equations are imposed, OLS is no longer adequate. Since the symmetry condition is usually imposed, both MLE and GLS have a clear advantage over OLS when estimating the DFAM.

The MLE procedure has some advantages over GLS when estimating the DFAM. As mentioned before, one advantage is that parameter estimates estimated using MLE are invariant to the equation deleted from the system while GLS estimates may vary depending on the equation deleted. Also MLE links up with the Likelihood Ratio test which can be used to verify hypotheses about the system (Barten, 1969).

Goodness of Fit Measures

When estimating a system of equations such as the DFAM, it is not particularly useful to discuss the coefficient of determination measure (R^2) for each individual equation in the system. A more useful measure would be one that accesses the overall fit of the entire system. A system-wide goodness of fit measure is more useful because the DFAM is properly estimated jointly and this measure would determine the goodness of fit of that joint estimation procedure.

The goodness of fit measure used in this study is the goodness of fit measure presented by McElroy (1977) to be used with the feasible GLS procedure for the SUR problem. Similar to the way the single equation R^2 is derived, this goodness of fit measure is derived by taking the total sum of squares of the entire system of equations. The total sum of squares for the entire system is

$$Y'(S^{-1} \otimes A)Y' = \hat{B}'_{FGLS} X'(S^{-1} \otimes A)X\hat{B}_{FGLS} + e'(S^{-1} \otimes I)e \qquad (4.34)$$

where Y and X are defined in equation (4.10), S^{1} is the inverse of S, which is defined in equation (4.19) and $\hat{B}_{FGLS}$ is defined in equation (4.20). A is the matrix that transforms variables into their deviation from mean form and it is

$$A = I_{(T)} - \frac{1}{T}\iota\iota' \qquad (4.35)$$

where **I** is the identity matrix, T is the total number of observations, and ι is a column vector of T units. Note that in equation (4.34), the term on the left is the total sum of squares and the first and second terms on the right are the explained and unexplained sum of squares respectively. In the single equation case

$$R^2 = \frac{explained\ SS}{total\ SS} = 1 - \frac{unexplained\ SS}{total\ SS}. \qquad (4.36)$$

The same applies to the equation system. The goodness of fit measure for a system of equations that is estimated using FGLS is

$$R^2_M = \frac{\hat{B}'_{FGLS} X'(S^{-1} \otimes A)X\hat{B}_{FGLS}}{Y'(S^{-1} \otimes A)Y'} = 1 - \frac{e'(S^{-1} \otimes I)e}{Y'(S^{-1} \otimes A)Y'}. \qquad (4.37)$$

Note that equation (4.37) is bounded on [0,1] and is maximized when the FGLS procedure is used. This equation can also be used with MLE by replacing the GLS estimates with the MLE estimates of B and Σ. (McElroy, 1977).

Equation (4.37) has some drawbacks when used for the DFAM or any SUR system. As mention before, the estimation of the DFAM requires that an equation be deleted from the system. Given that the sum of squares will vary with the equation deleted, the goodness of fit measure will also vary depending on the equation deleted.

Greene (1997) notes that goodness of fit measures of this type are purely descriptive and should be used with care when comparing it to the fit of another system and that the McElroy measure is biased toward unity. The reason is that this measure may often be an aggregate of mediocre fits giving an apparent good fit overall.

Bewley (1986) presents a goodness of fit measure derived from equation (4.37) that utilizes the Wald test statistic. This measure is

$$R_W^2 = 1 - \frac{1}{1 + W^* / (T-k)(n-1)} \tag{4.38}$$

where W^* is the Wald statistic that forces all the coefficients in the system to zero. T is the number of observations, n is the number of equations in the full system, and k is the number of regressors in each equation.

Seale, Sparks, and Buxton used equation (4.38) as a goodness of fit measure with the Rotterdam model to estimate the import demand for fresh apples. Values ranged from as high as .97 to as low as .57. The equation deleted from the system was the rest of the world equation, which was the least important equation to the study. However, given these measures tendency toward unity, it may not be appropriate to use them as a measure for explained variation in the dependent variable. Therefore in addition to these measure it is important to consider the significance of individual parameters as an indicator of the reliability of the data to represent the system. In this study equation (4.38) will be used as well; however, it will be used with caution.

Autocorrelation and the DFAM

The use of log changes over time in the DFAM requires taking the logged first difference of the variables. This procedure is often a correction for autocorrelation, although it is not its purpose (Barten, 1977). Even when first differences are taken, there may still exist the possibility of autocorrelation; however its existence will be less probable than cases when the first difference is not taken as in other demand systems. With this said, autocorrelation issues must be considered when estimating this model. The purpose of this section is to first investigate ways in which to determine the presence of autocorrelation in a system of equations, and second to present the procedures used for the correction of the first order autoregressive process.

For a single equation, the mostly widely used test is the Durbin-Watson (DW) test. However use of the DW statistic for a system of equations may not give clear results as in the single equation case. Bewley (1986) indicates that given the adding-up constraint, it is not possible to have autocorrelated residuals in only one equation and that the autoregressive process should be the same for each equation. For example, given a first order autoregressive disturbance (AR(1) process) for the ith equation, $\varepsilon_{it} = \rho \varepsilon_{it-1} + \mu_t$, ρ should be the same for each equation. Therefore a DW test on each individual equation should either indicate the presence of auto correlation in all equations or none at all. Overall, Bewley suggests that the DW statistic can be used as a guide for the possible existence of autocorrelation; however it should not be used as an indication of the absence of autocorrelation. Furthermore, Berndt and Savin (1975) note that if ρ is specified such that it is not common across equations, then ML estimation no longer yield parameters invariant to the equation deleted.

In addition to the DW test, Bewley also presents a generalization of the DW statistic used by Theil

$$T_a = T^{-1}\, trace \hat{\Omega}^{-1}(\hat{\mu} - \hat{\mu}_{-1})'(\hat{\mu} - \hat{\mu}_{-1}).^{5} \tag{4.39}$$

Unfortunately, the distribution of this test statistic is complicated by the joint estimation of Ω and μ and a subjective decision must be made on the basis that $0 \le T_a \le 4(n-1)$ with $T_a = 2(n-1)$ under the null hypothesis of no autocorrelation.

Lastly, a likelihood ratio test comparing a specific autocorrelated version of the DFAM with the general version could be performed. The benefit of this method is that the test statistic will have an exact distribution, yielding fewer ambiguous results than the previously discussed methods. However, this method requires the estimation of the DFAM with and without autocorrelated disturbances. For this test, the AR(1) version of the DFAM is the unrestricted model and the DFAM without AR(1) is the restricted model. The likelihood ratio test is

$$LR = -2[\ln L_r - \ln L_u] \xrightarrow{d} \chi^2[J] \tag{4.40}$$

where $\ln L_r$ and $\ln L_u$ are the log likelihood values for the restricted and unrestricted models respectively. LR is distributed χ^2 with J degrees of freedom, where J is the number of restrictions, which is 1 when a common ρ is specified (Berndt & Savin, 1975; Green et al., 1978; Beach & MacKinnon, 1979).

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[5] $(\hat{\mu} - \hat{\mu}_{-1})$ is a vector of disturbance differences where each element is $\mu_t - \mu_{t-1}$, and $\hat{\Omega} = \hat{\mu}'\hat{\mu}\ (1/T)$.

The DFAM with an AR(1) disturbance process is

$$\bar{f}_{it} D x_{it} = \theta_i D X_t + \sum_{j=1}^{n} \pi_{ij} \, D w_{jt} + \tilde{\varepsilon}_{it} \qquad (4.41)$$

where $\tilde{\varepsilon}_{it} = \rho \tilde{\varepsilon}_{it-1} + \mu_t$ and $E[\mu_t] = 0$, $E[\mu_t^2] = \sigma^2(\mu)$, and $\mathrm{Cov}[\mu_t, \mu_s] = 0$, if $t \neq s$.

Recall the SUR variance/covariance block matrix, (*V*=Σ⊗*I*), where each block of *V* is $\sigma_{ij} \boldsymbol{I}$. If we assume an AR(1) process, the blocks of *V* are $\sigma_{ij} \boldsymbol{\Omega}_{ij}$, where

$$\boldsymbol{\Omega}_{ij} = \begin{bmatrix} 1 & \rho_j & \rho_j^2 & \cdots & \cdots & \rho_j^{T-1} \\ \rho_i & 1 & \rho_j & \cdots & \cdots & \rho_j^{T-2} \\ \rho_i^2 & \rho_i & 1 & \cdots & \cdots & \rho_j^{T-3} \\ & & \vdots & & & \\ & & \vdots & & & \\ \rho_i^{T-1} & \rho_i^{T-2} & \rho_i^{T-3} & \cdots & \cdots & 1 \end{bmatrix}. \qquad (4.42)$$

As mentioned, ρ is equal across equations due to the adding up constraint in the DFAM which says that the AR(1) process is not unique to each equation (i.e. $\rho_i = \rho_j$). With this said, the block matrix *V* with AR(1) disturbances is Σ⊗***Ω***.

The FGLS method of estimating the Rotterdam model can be extended to allow for the AR(1) process. However, in this instance a consistent estimator of ***Ω*** as well as Σ is needed. Parks (1967) presents a three-step approach laid out in Greene (1997, p. 687).

1. Estimate each equation in the system by OLS and obtain a consistent estimator of ρ. Using the ρ estimate, transform the data for each equation using the Pras-Winsten transformation or the Cochrane-Orcutt procedure to remove the Autocorrelation.

2. Using the transformed data, use OLS once more to estimate Σ.

3. Follow the FGLS procedure using the estimated Σ and the transformed data.

This estimator is efficient at every step, and iteration does not produce the ML estimator. After the last step, Σ should be re-estimated using the FGLS estimates. Note the variance/covariance matrix for ε can be reconstructed using

$$\hat{\sigma}_{ij}(\varepsilon) = \frac{\hat{\sigma}_{ij}(\mu)}{1-r^2}. \tag{4.43}$$

A consistent estimator of ρ using the OLS residuals is

$$r = \frac{\sum_{t=2}^{T} e_t e_{t-1}}{\sum_{t=2}^{T} e_t^2}. \tag{4.44a}$$

Other modifications are

$$r^* = \left[\frac{T-K}{T-1}\right] r \tag{4.44b}$$

$$r^{**} = 1 - \frac{d}{2} \tag{4.44c}$$

where d is the DW statistic (Greene, 1997). Since OLS is performed on each equation separately, r is estimated for each equation, which may not give a common estimator across equations. Four possible estimators to get a common r are

$$\bar{r} = \frac{1}{n}\sum_{i=1}^{n} r_i \tag{4.45a}$$

$$r = \frac{\sum_{i=1}^{n}\sum_{t=2}^{T} e_t e_{t-1}}{\sum_{i=1}^{n}\sum_{t=2}^{T} e_t^2} \tag{4.45b}$$

$$\tilde{r} = \text{sample } Corr[e_{i,t-1}, e_{it}] \tag{4.45c}$$

$$\bar{\bar{r}} = \sum_i w_i r_i \ , w_i = \frac{1/(1-r_i^2)}{\sum_{i=1}^{n} 1/(1-r_i^2)} . \tag{4.45d}$$

Each of these is consistent (Greene, 1997).

Once a consistent estimator of ρ is obtained, the data must be transformed using either the Prais-Winsten transformation or the Cochrane-Orcutt procedure. In order to do either of these procedures, we must first define a matrix $\boldsymbol{P}$ such that $\boldsymbol{P'P} = \boldsymbol{\Omega}^{1}$. It can be shown that this matrix is given by:

$$\boldsymbol{P} = \begin{bmatrix} \sqrt{(1-\rho^2)} & 0 & 0 & \cdots & 0 \\ -\rho & 1 & 0 & \cdots & 0 \\ 0 & -\rho & 1 & \cdots & 0 \\ 0 & 0 & -\rho & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix} . \tag{4.46}$$

If we let $\boldsymbol{y}_i = \boldsymbol{X}_i\boldsymbol{B}_i + \boldsymbol{\varepsilon}_i$ be the ith equation in the Rotterdam system, then pre-multiplying by $\boldsymbol{P}$ yields $\boldsymbol{y}_i{*} = \boldsymbol{X}_i{*}\boldsymbol{B}_i + \boldsymbol{\varepsilon}_i{*}$ where

$$\boldsymbol{y}_i^* = \begin{bmatrix} \sqrt{(1-\rho^2)}\ y_1 \\ y_2 - \rho y_1 \\ \vdots \\ y_T - \rho y_{T-1} \end{bmatrix} \tag{4.47}$$

$$\boldsymbol{X}_i^* = \begin{bmatrix} \sqrt{(1-\rho^2)}\ x_1 \\ x_2 - \rho x_1 \\ \vdots \\ x_T - \rho x_{T-1} \end{bmatrix} \tag{4.48}$$

$$\boldsymbol{\varepsilon}_i^* = \begin{bmatrix} \sqrt{(1-\rho^2)}\,\varepsilon_1 \\ \varepsilon_2 - \rho\varepsilon_1 \\ \vdots \\ \varepsilon_T - \rho\varepsilon_{T-1} \end{bmatrix}. \tag{4.49}$$

Equations (4.47), (4.48), and (4.49) are commonly referred to as partial differences, quasi differences, or pseudodifferences (Greene, 1997). The above mentioned transformation procedure is the Prais-Winsten transformation. The Cochrane-Orcutt procedure is the same except that the first observation is deleted. In large samples, there should be no difference in the procedure chosen to remove the autocorrelation from the data; however, in small samples, this is not the case. Greene suggests that the cost of deleting the first observation is almost surely greater than that of neglecting to account properly for the correlation of the first disturbances with the other first disturbances. With this said, the Prais-Winsten transformation is preferred with small samples.

If we transform each equation in the DFAM, equations (4.9) and (4.10) become

$$\begin{bmatrix} y_1^* \\ y_2^* \\ \cdots \\ y_n^* \end{bmatrix} = \begin{bmatrix} X_1^* & 0 & 0 & 0 \\ 0 & X_2^* & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & X_n^* \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdots \\ \beta_n \end{bmatrix} + \begin{bmatrix} \varepsilon_1^* \\ \varepsilon_2^* \\ \cdots \\ \varepsilon_n^* \end{bmatrix} \tag{4.50}$$

$$\boldsymbol{Y^*} = \boldsymbol{X^*B} + \boldsymbol{\varepsilon^*}. \tag{4.51}$$

The FGLS and MLE procedures can be done exactly as describe in the previous sections.

Full maximum likelihood estimation of the DFAM autocorrelated disturbances can be obtained in a similar manner as previously described. However, there is the added parameter ρ that must be estimated as well. Using equation (4.51), the log-likelihood function for the DFAM where the error term follows an AR(1) process is

$$\begin{aligned}\ln L = consant - \frac{T(n-1)}{2}\ln\left|V(\varepsilon^*)\right| - \frac{n-1}{2}\ln(1-\rho^2) \\ -\frac{1}{2}\varepsilon^{*\prime}V(\varepsilon^*)^{-1}\varepsilon^*\end{aligned} \quad . \tag{4.52}$$

$V(\varepsilon^*)$ is the variance matrix for the AR(1) system. Note that the variance of ε (from equation (4.10)) can be recovered from using the following equation

$$V(\varepsilon) = \frac{1}{1-\rho^2}\left[V(\varepsilon^*)\right]. \tag{4.53}$$

One possible means of obtaining the ML estimate of ρ is to search the range $1<\rho<1$ for a value of ρ that maximizes the log-likelihood function given the OLS value of B. Once an estimate of ρ is found, the Prais-Winsten transformation or Cochrane-Orcutt procedure can be used to remove the auto-correlation from the data. Note that with an estimate of ρ, the third term in the equation (4.52) becomes part of the constant term and any of the MLE iteration procedures can now be used to find estimates of B and $V(\varepsilon^*)$.

Another means of obtaining ML estimates of ρ, B, and $V(\varepsilon^*)$ is to design an iterative scheme where each of these values are obtained simultaneously. Recall the method of scoring described in the previous section. This iterative procedure made use of the information matrix as a means of obtaining an estimate of the parameter vector.

The parameter ρ can also be included in this iterative scheme. The information matrix for a system of equations where ρ is included as a parameter is

$$I(B, V(\varepsilon^*), \rho) = \begin{bmatrix} X'P'\hat{V}(\varepsilon^*)^{-1}PX & 0 & 0 \\ 0 & \frac{n}{2}(\hat{V}(\varepsilon^*)^{-1})^2 & \frac{\rho}{1-\rho^2}\hat{V}(\varepsilon^*) \\ 0 & \frac{\rho}{1-\rho^2}\hat{V}(\varepsilon^*) & \frac{(n-1)T-2}{1-\rho^2} + \frac{1+\rho^2}{(1-\rho^2)^2} \end{bmatrix}. \tag{4.54}$$

The method of scoring can be performed as before. Note that equation (4.54) is the information matrix with the first observation retained. If the first observation is removed, equation (4.54) is simplified; however, as in the previous cases, removal of the first observation is discouraged (Greene, 1997).

In this study, the estimate of the autocorrelation parameter ρ will be obtained using full ML estimation where ρ will be common across equations. This procedure is found in Berndt and Savin (1975), Green et al. (1978) and Beach and MacKinnon (1979). The test for autocorrelation will be performed using the likelihood ratio test. In this procedure the DFAM model will be estimated with and without AR(1) disturbances. The likelihood ratio test (equation (4.40)) will then be used to test the hypothesis $\rho = 0$, where the DFAM with non-autocorrelated disturbances will be the restricted model. If autocorrelation can not be rejected, then the autocorrelated DFAM will be used to test for economic properties and forecasting.

Testing Economic Theory

A key feature of the DFAM is that production theory can be tested or imposed upon the system to determine if the data is consistent with theory. The properties discussed in Chapter 3, homogeneity, symmetry, and negative semi-definiteness can be tested, imposed, or checked.

The property of homogeneity says that the input mix is only effected by relative price changes. The properties of symmetry and negative semi-definiteness of the price coefficient matrix are a direct result of the cost function being concave. The concavity of the cost function suggest that given an optimal input mix for a given vector of input prices, if prices change, the cost of that same input mix will always be greater than the cost of a new optimal input mixed. In other words, a linear combination is always above the curve (Mas-Colell et al., 1995). Mathematically we know that the Hessian of a concave function is symmetric and negative semi-definite. Given that the matrix of derivatives of the factor demands with respect to prices is the Hessian of the cost function (Shepard's Lemma), it is symmetric and negative semi-definite (Mas-Colell et al., 1995).[6]

The homogeneity property in the DFAM model is satisfied when $\sum_j \pi_{ij} = 0$. Recall the parameter vector $\boldsymbol{B}'=[\boldsymbol{B}'_1, \boldsymbol{B}'_2, \ldots \boldsymbol{B}'_n]$, where each $\boldsymbol{B}_i'=[\theta_i, \pi_{i1}, \pi_{i2}, \ldots \pi_{in}]$. If we let $\boldsymbol{a}=[0\ 1\ \ldots 1]'$, then the homogeneity property can be written as $\boldsymbol{a}'\boldsymbol{B}_{i.}=0$. For the entire system with one equation deleted for estimation, this property is expressed as $\boldsymbol{RB}=[\boldsymbol{0}]$, where $\boldsymbol{R}=\boldsymbol{I}_{(n-1)} \otimes \boldsymbol{a}'$. Given the assumption that the disturbance term is normally distributed with zero mean and a constant contemporaneous covariance matrix $\Sigma \otimes \boldsymbol{I}_{(T)}$ and that they are independent over time, the test used to validate this hypothesis is

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[6] The symmetry property in the DIA model is derived from the relationship $\partial x_i / \partial w_j = \partial x_j / \partial w_i$, where it can be shown that $f_i \varepsilon_{ij} = f_j \varepsilon_{ji}$, which implies that $\pi_{ij} = \pi_{ji}$. ε is the own and cross price factor demand elasticity.

$$F^* = \frac{\hat{\boldsymbol{B}}'\boldsymbol{R}'\Sigma^{-1}\boldsymbol{R}\hat{\boldsymbol{B}} / \boldsymbol{a}'(\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{a}}{trace\Sigma^{-1}\boldsymbol{S}}, \tag{4.55}$$

which is distributed as an F statistic with n-1 and (n-1)(T-n-1) degrees of freedom under the null hypothesis of equation $\boldsymbol{RB} = [\boldsymbol{0}]$.[7] The application of equation (4.55) requires that we replace Σ^{-1} with $\boldsymbol{S}^{-1}$ since Σ is usually unknown. This replacement changes the denominator to a constant (n-1) and equation (4.55) becomes

$$\overline{\overline{W}} = \hat{\boldsymbol{B}}'\boldsymbol{R}'\boldsymbol{S}^{-1}\boldsymbol{R}\hat{\boldsymbol{B}} / \boldsymbol{a}'(\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{a} \tag{4.56}$$

which is asymptotically distributed as χ^2 with (n-1) degrees of freedom (Theil, 1971).

Several studies that used equation (4.56) indicated a rejection of homogeneity (e.g., Barten, 1969). Laitinen (1978) investigated why was homogeneity so often rejected when the Rotterdam model was used. He found that equation (4.38) was biased toward rejection, particularly for large systems due to the use of the least squares estimated covariance matrix $\boldsymbol{S}$. Using simulation data where homogeneity was satisfied by construction, results indicated that as n increased, the percentage of rejections out of 100 trials also increase. For example, at the five percent level for n=5, 8, 11, and 14, the percentage of rejections were 14, 30, 53, and 87 respectively when equation (4.56) was used. Given that a simulation experiment has the advantage of everything being known, the actual covariance matrix was used to compute equation (4.56). The results indicated a significant drop in the number of rejections by over 80 percent when n=14.

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[7] $\hat{\boldsymbol{B}}$ is the unrestricted least squares estimator for $\boldsymbol{B}$ which is also the GLS and MLE estimator.

The problem with equation (4.56) is related to the degrees of freedom. For $\boldsymbol{S}$ to be non-singular $T-2n \geq 0$ must hold. As $\boldsymbol{S}$ approaches singularity, equation (4.56) approaches infinity. As systems become large, T-2n approaches zero, which leads to large values of equation (4.56) and the rejection of the null hypothesis.

In addition to the previous findings, Laitinen also succeeded in deriving an exact distribution of equation (4.56). He indicated that under the null hypothesis of homogeneity, equation (4.56) is distributed as a Hotelling's T^2 statistic, which is itself distributed as a multiple $(n-1)(T-n-1)/(T-2n+1)$ of the F statistic with n-1 and T-2n+1 degrees of freedom. Using this statistic, the percentage of rejections was greatly reduced.

Homogeneity can be imposed on the system prior to estimation instead of testing the unrestricted model. The homogeneity property is satisfied when $\sum_j \pi_{ij} = 0$. This implies that $\pi_{in} = -\pi_{i1} - \pi_{i2} - \cdots - \pi_{in-1}$. If we substitute for π_{in} in the DFAM, it becomes

$$\bar{f}_{it} D_{it} = \theta_i DX_t + \sum_{j=1}^{n-1} \pi_{ij} \left(D w_{jt} - D w_{nt}\right) + \varepsilon_{it} \tag{4.57}$$

which indicates that homogeneity is imposed upon the DFAM by deflating each price by the price of good n (Theil, 1971). Any of the previous estimation procedures can be used to estimate equation (4.39). Note that OLS is still an option because even with homogeneity imposed, the matrix of explanatory variables is the same for each equation. If MLE is used to estimate the unrestricted and the homogeneity restricted model, a likelihood ratio test can be used to test for homogeneity. Seale, Sparks and Buxton (1992) used a LR test to determine the validity of homogeneity and found that it could not be rejected.

Either of the procedures discussed is adequate for testing homogeneity. When the system is small or there is a large difference between T and $2n$, the asymptotic χ^2 test based on $\boldsymbol{S}$ may be considered. However, given Laitinen's results on the exact distribution of equation (4.56), it would be better to use the Hotelling's T^2 distribution, which is clearly in favor of not rejecting the null hypothesis.

Given the adding up constraint, symmetry cannot be considered in the absence of homogeneity. The reason is symmetry implies homogeneity when adding up is satisfied. Therefore, symmetry must always be tested on the homogeneity-constrained model or used as a constraint with homogeneity imposed.

Let $\boldsymbol{Y}=\boldsymbol{X}^h\boldsymbol{B}^h+\boldsymbol{\varepsilon}$ be the homogeneity constrained DFAM, where $X^h = [DQ \quad Dp_1 - Dp_n \quad \cdots \quad Dp_{n-1} - Dp_n]'$ and $B_i^h = [\theta_i \ \pi_{i1} \ \pi_{i2} \cdots \pi_{i,n-1}]'$ are the homogeneity constrained matrix of independent variables and corresponding vector of parameters. If n=4, the symmetry constraint is expressed as $\boldsymbol{RB}^h$=[**0**] where

$$\begin{array}{cc} & \begin{array}{cccccccccccc} \theta_1 & \pi_{11} & \pi_{12} & \pi_{13} & \theta_2 & \pi_{21} & \pi_{22} & \pi_{23} & \theta_3 & \pi_{31} & \pi_{32} & \pi_{33} \end{array} \\ \boldsymbol{R}= & \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \end{bmatrix} \end{array} .$$

The test statistic for $\boldsymbol{RB}^h$=[**0**] is

$$F^{**} = \frac{\hat{\boldsymbol{B}}^{h\prime}\boldsymbol{R}'\{\boldsymbol{R}[\Sigma \otimes (\boldsymbol{X}'\boldsymbol{X})^{-1}]\boldsymbol{R}'\}^{-1}\boldsymbol{R}\hat{\boldsymbol{B}}^h}{[J/(n-1)]trace\Sigma^{-1}\boldsymbol{S}} \tag{4.58}$$

which is distributed as an F statistic with J and $(n-1)(T-n)$ degrees of freedom under the null hypothesis, where J equal the number of restricted parameters. Again we must replace Σ with $\boldsymbol{S}$ and equation (4.58) becomes

$$\overline{\overline{W}}{*} = \hat{\boldsymbol{B}}^{h}{'}\boldsymbol{R}'\{\boldsymbol{R}[\boldsymbol{S}\otimes(\boldsymbol{X}'\boldsymbol{X})^{-1}]\boldsymbol{R}'\}^{-1}\boldsymbol{R}\hat{\boldsymbol{B}}^{h} \tag{4.59}$$

which is asymptotically distributed as χ^2(J) under the null hypothesis (Theil and Clements, 1987).

As in the homogeneity case, the use of equation (4.59) leads to numerous rejections of the null hypothesis when n is large (n=11 or greater). For n=14, equation (4.59) led to 96 rejections out of 100 at the 5 percent significance level. However, Meisner (1979) showed using a simulation experiment that when the true variance matrix is used instead of $\boldsymbol{S}$, 6 out of 100 rejections occurred at most for various n up to 14. However when n is small (n=5), equation (4.59) performed slightly better than the homogeneity test using $\boldsymbol{S}$. Out of 100 simulated trails, equation (4.59) led to only 9 rejections when n=5.

Symmetry constrained estimation could be done using either GLS or MLE where the symmetry constrained GLS estimator is

$$\hat{\boldsymbol{B}}{*} = \hat{\boldsymbol{B}} - \boldsymbol{CR}'(\boldsymbol{RCR}')^{-1}\boldsymbol{R}\hat{\boldsymbol{B}}, \tag{4.60}$$

and the covariance matrix of this estimator is

$$Var[\hat{\boldsymbol{B}}{*}] = \boldsymbol{C} - \boldsymbol{CR}'[\boldsymbol{RCR}']^{-1}\boldsymbol{RC} \tag{4.61}$$

where $C=\Sigma\otimes(X'X)^{-1}$(Theil, 1971).[8]

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[8] Note that $\hat{\boldsymbol{B}}$ is the homogeneity-constrained estimator.

As before, Σ must be replaced with $\boldsymbol{S}$. Theil and Clements (1987) show using a simulation experiment that two problems arise when using $\boldsymbol{S}$. One is that coefficient estimates have an impaired efficiency and two, approximate standard errors give an overly optimistic picture of their precision.

The symmetry constrained ML estimator can be obtained using the iterative procedures previously presented. Let $\tilde{\boldsymbol{X}}$ and $\tilde{\boldsymbol{\Theta}}$ represent the symmetry augmented matrix of independent variables and parameter vector, where for n=4,

$$\tilde{X} = \begin{bmatrix} DQ & Dp_1^h & Dp_2^h & Dp_3^h & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & Dp_1^h & 0 & DQ & Dp_2^h & Dp_3^h & 0 & 0 \\ 0 & 0 & 0 & Dp_1^h & 0 & 0 & Dp_2^h & DQ & Dp_3^h \end{bmatrix}$$

and $\tilde{\boldsymbol{\Theta}} = [\theta_1\ \pi_{11}\ \pi_{12}\ \pi_{13}\ \theta_2\ \pi_{22}\ \pi_{23}\ \theta_3\ \pi_{33}]'$.[9] The iterative procedure that can be used is

$$\hat{\tilde{\boldsymbol{\Theta}}}_{new} = \hat{\tilde{\boldsymbol{\Theta}}}_{old} + \left[\tilde{X}'\hat{V}^{-1}\tilde{X}\right]^{-1}\tilde{X}'\hat{V}^{-1}\varepsilon. \tag{4.62}$$

Note that $\hat{\boldsymbol{V}}$ and $\boldsymbol{\varepsilon}$ are the covariance matrix and disturbance term derived from $\boldsymbol{X}^h$ (the h superscript denotes homogeneity constrained) and $\hat{\boldsymbol{\Theta}}^{hs}$, where

$$\boldsymbol{\Theta}^{hs} = [\theta_1\ \pi_{11}\ \pi_{12}\ \pi_{13}\ \theta_2\ \pi_{12}\ \pi_{22}\ \pi_{23}\ \theta_3\ \pi_{13}\ \pi_{23}\ \pi_{33}]'.^{10}$$

The iterative procedure is done in the following manner.

1. First, pick values for the vector Θ_{old}^{hs} and find ε and $\hat{V}^{-1}$ using the formulas in footnote 10.

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[9] $Dp_i^h = Dp_i - Dp_4$ (homogeneity).

[10] $\varepsilon = [\varepsilon_1'\varepsilon_2'\varepsilon_3']$, where $\varepsilon_i = y_i - X^h\Theta^{hs}$. $\hat{V} = \hat{\Sigma} \otimes I_{(T)}$, where the elements of $\hat{\Sigma}$ are $(1/T)\varepsilon_i\varepsilon_j$.

2. Use $\boldsymbol{\Theta}_{old}^{hs}$ to construct $\tilde{\boldsymbol{\Theta}}_{old}$ by removing the second of the symmetric parameters.
3. Find $\tilde{\boldsymbol{\Theta}}_{new}$ using equation (4.62) and reconstruct $\boldsymbol{\Theta}_{new}^{hs}$ using the updated estimates and repeat the above steps until convergence.

As before a likelihood ratio test can be used to validate the symmetry hypothesis. However, the unrestricted model is now the homogeneity-constrained model and the restricted model is the symmetry constrained model with homogeneity already imposed. The test statistic is distributed as $\chi^2(J)$, where J is the number of restricted parameters in excess of the homogeneity restrictions.

Overall evidence suggests that the use of the consistent estimator $\boldsymbol{S}$ lead to numerous rejections of both homogeneity and symmetry when the size of the system is large. Although there is a correction that can be used in the homogeneity case, no such correction is suggested for symmetry. When the size of the system is small, tests based on $\boldsymbol{S}$ are somewhat more reliable, although they do lead to slightly more rejections. The problem with symmetry constrained estimation when $\boldsymbol{S}$ is that coefficient estimates have impaired efficiency and approximate standard errors give an overly optimistic picture of their precision.

Seale, Sparks and Buxton (1992); Weatherspoon and Seale (1995); and Pana-Cryan (1996) all used MLE and likelihood ratio test to test these economic properties. In each of these studies neither of these properties could be rejected. However, each of these studies had relatively small systems (*n* around 5). Evidence suggests the likelihood ratio test perform better than the Wald test statistics previously describe.

Negative semi-definiteness (n.s.d.) can be verified in three ways. First, the eigenvalues of a matrix are all less than or equal to 0. Second, the quadratic form of a matrix is less than or equal to 0. Third, the determinants of the leading principle minors alternate in being less than or equal to or greater than or equal to 0, with the first determinant being less than or equal to zero (Mas-Colell et al., 1995).

The n.s.d. property says that the matrix of price coefficients, $\Pi=[\pi_{ij}]$ is negative semi-definite. This property can be verified by checking any of the three conditions stated. Some studies have suggested that n.s.d. is necessarily verified but not sufficiently verified when the own price coefficients are negative e.g. Pana-Cryan (1996) and Rougier(1997). However, this condition is neither necessary nor sufficient for n.s.d. If all of the own price coefficients are negative, this suggests that the trace of the matrix is negative, which also implies that the sum of the eigenvalues is also negative. However the sum of the eigenvalues being negative does not imply that each eigenvalue is less than or equal to zero. Reversing this chain, if all eigenvalues are non-positive, this suggest that the sum and the trace is also non-positive, but this need not imply that every diagonal element is non-positive. Therefore inspecting the diagonal elements of Π to check if they are all non-positive does not indicate that a matrix is n.s. definite. To properly verify n.s.d. once Π is estimated, use any of the three methods previously described. However, when checking for n.s.d., in particular when checking the eigenvalues, a question should arise, how should the significance of an eigenvalue be determined? For example, if an eigenvalue is positive, n.s.d. may still be valid if this value is not significantly different form zero. Although, this cannot be determined by inspection alone some judgement can still be made.

In this study, the validity of homogeneity and symmetry is assessed using constrained MLE and the likelihood ratio test. The property of negative semi-definiteness is verified by inspection of the eigenvalues of the price coefficient matrix. If any of the values are questionable, judgements will be made based on the standard errors of the price coefficient estimates.

Forecasting and the DFAM

The dependent variable in the DFAM involves a nonlinear transformation of the left-hand side of equation (4.8) in order to make quantity demanded forecast. Given the structure of the left-hand side, predicted and expected quantities are not trivially derived. The DFAM thus requires special manipulation when used for forecasting.

Kastens and Brester (1996) suggest two procedures to allow for forecasting with the DFAM.[11] The first procedure requires taking a second order Taylor's series expansion of the predicted left-hand side of the DFAM, equation (4.8). This procedure results in an equation that can be used to predict out-of-sample quantity for each equation in the system, where the predicted values are based on the model estimates. Unlike Kastens and Brester (1996), this study presents a method for forecasting without taking a Taylor's series expansion; however, the resulting equation is presented in the next chapter. The complexity of the left-hand side of equation (4.8) and the model used in Kastens and Brester required an iteration procedure such as the Gauss-Siedel algorithm on the equation used to forecast quantity.

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[11] This study used the Rotterdam model; however, the Rotterdam model and the DFAM are structurally similar.

The second procedure was elasticity based. By defining the small changes in prices and income to be exactly those that actually occurred from year to year, forecasts of per capita consumption were derived from elasticity estimates. The equation used was

$$q_{i,t} = \left(\sum_{j=1}^{n} \eta_{ij} \left[\frac{p_{j,t} - p_{j,t-1}}{p_{j,t-1}} \right] + \eta_i \left[\frac{x_{j,t} - x_{j,t-1}}{x_{j,t-1}} \right] \right) q_{i,t-1} + q_{i,t-1} \tag{4.63}$$

where q represents per capita consumption of a particular good within the system, p represents the prices, and x is income. η_{ij} and η_i is the own and cross-price elasticity, and income elasticity respectively. This procedure can be applied to the DFAM; however, q would be the quantity demanded for the input or imported good and x would be the Divisia input index. Also, the income elasticity would now be the Divisia elasticity presented in chapter 3.

Kastens and Brester (1996) found that the elasticity based forecast were far superior to the model-based forecast when using the Rotterdam model. Precision in forecast estimates improved by as m as 37 percent when moving away from model based statistical forecasting to forecasting using mean-based elasticities.

In this study a similar procedure will be performed. Each of the DFAM systems will be estimated using all except the last 4 to 5 years of the data sets. Using both model-based and elasticity-based forecasting method for the remaining years, the precision of each of these methods when compared to the actual values for the remaining years will determine which of the two procedures to use in forecasting and simulations for future periods.

Summary

In summary, the model that will be estimated will be equation (4.8). The procedure that will be used to estimate the system represented by equations (4.8) will be the multivariate Gauss-Newton method shown in equation (4.32). This method will be performed using the LSQ procedure in the Times Series Processor (version 4.5) (TSP).

In this study equation (4.38) will be used as the goodness of fit measure to evaluate the fits of the systems estimated. This measure is not difficult to calculate and it only requires the Wald statistic for the hypothesis test that forces all of the coefficients to zero. The Wald statistic for the entire system is obtained in TSP. If the resulting system fit measures are overly optimistic, the R^2 for each equation will also be discussed.

The estimate of the autocorrelation parameter ρ will be obtained using full MLE. The test for autocorrelation will be performed using the likelihood ratio test. In this procedure the DFAM will be estimated with and without AR(1) disturbances. The likelihood ratio test (equation (4.40)) will then be used to test the hypothesis $\rho = 0$, where the DFAM with non-autocorrelated disturbances will be the restricted model. If autocorrelation can not be rejected, then the autocorrelated DFAM will be used to test for economic properties and forecasting.

The validity of homogeneity and symmetry is assessed using constrained MLE and likelihood ratio test. The LSQ procedure in TSP gives the log likelihood values for each system that is estimated. Deflating the prices within the system as describe in this chapter will impose homogeneity, and restricting the symmetric parameter to be equal will impose symmetry. In both instances the LSQ procedure in TSP will give the log likelihood values which can be used for the LR test. The negative semi-definiteness property is verified by inspection of the eigenvalues of the price-coefficient matrix. If any of the values are questionable, judgements will be made based on the standard errors of the price coefficient estimates.

Lastly, using both the model-based and elasticity-based forecasting method to forecast within sample quantities, the precision of each of these methods will determine which of the two procedures to use in forecasting and simulations for future periods. Unlike Kastens and Brester (1996), this study presents a method for forecasting without taking a Taylor's series expansion. The Gauss-Siedel algorithm will be used to solve for the forecasted quantities in the model-based and elasticity-based equations.

CHAPTER 5
METHODOLOGY

Econometric Model and Estimation

The econometric model that will be used to estimate the derived demand for imported dairy products in selected international markets for the U.S. is derived from the equation presented in the previous chapter, equation (4.8). Referred to as the differential factor allocation model (DFAM), this equation is

$$\bar{f}_{it} D\, x_{it} = \theta_i D\, X_t + \sum_{j=1}^{n} \pi_{ij}\; D\, w_{jt} + \tilde{\varepsilon}_{it}\,. \tag{5.1}$$

$Dx_t = \log(x_t)-\log(x_{t-1})$ and $Dw_t = \log(w_t)-\log(w_{t-1})$ are the log change in quantity and price respectively from period *t*-1 to *t*. $\bar{f}_{it} = (f_{it} + f_{it-1})/2$, where f_i is the *ith* factor share of total cost. *D*(*X*) is the finite version of the Divisa input index, where $DX_t = \sum_{i=1}^{n} \bar{f}_{it} D\, x_{it}$. π_{ij}'s are the price coefficients and θ_i is the marginal share of the *ith* input in marginal cost. Both are parameters to be estimated.

The target international markets selected for this study are Hong Kong, Japan, and Mexico. The individual dairy products considered are butter, cheese, dry milk, and whey. The exporting countries are the U.S., Australia, New Zealand, and the European Union (EU). For each target international market, a system of DFAM equations will be estimated for each individual dairy product where each individual equation is the import demand for an individual dairy product from an exporting source. If data permit, we have a total of 12 systems (4 for each importing country), where each system represents an importing country's demand for an individual dairy product from all possible sources. Take imports of cheese into Hong Kong for example. Equation (5.1) is the *ith* derived demand equation for imported cheese into Hong Kong from exporting country i, where $i \in$ (US, Australia, New Zealand, EU, ROW). ROW is the rest of the world, which in this instance is an aggregation of all imports of cheese into Hong Kong not imported from the primary source countries. This results in a 5-equation system where there is an equation for each exporting source. The Divisa input index is now an index of total cheese imports into Hong Kong. f_i is the total cost of cheese from source country i divided by the total cost of all cheese imported into Hong Kong. w_i's are the prices for imported cheese charged by the exporting countries. x_i is the quantity of cheese imported into Hong Kong from the *ith* exporting source.

Estimation of the system of equations represented by equation (5.1) will be accomplished using the LSQ procedure in the econometric program package Time Series Processor (TSP), version 4.4. The LSQ procedure in TSP when estimating the seemingly unrelated regression problem uses the multivariate Gauss-Newton method to estimate the parameters in the system. Recall from chapter 4 that this method is an iterative scheme derived from maximizing the log likelihood function. This procedure generates parameter estimates, standard errors, and probability values; also, a goodness of fit measure for each equation (R^2), the Durbin Watson statistic for each equation, and the log likelihood function value for the system. (Hall and Cummins, 1998)

Since the DFAM is a singular system due to the adding up constraint, an equation must be deleted from the system when using the LSQ procedure. The equation deleted is the ROW equation, which is the least important equation to the system. However, parameter estimates for this equation are recovered by re-estimating the system with another equation deleted and this one replaced. This is possible because parameter estimates are invariant to the equation deleted when using maximum likelihood estimation (Barten, 1969).

The system goodness of fit measure used is the measure presented by Bewley (1986). Recall from chapter 4 that this measure is

$$R_W^2 = 1 - \frac{1}{1 + W^* /(T-k)(n-1)} \tag{5.2}$$

where W^* is the Wald statistic that forces all the coefficients in the system to zero. T is the number of observations, n is the number of equations in the full system, and k is the number of regressors in each equation. The Wald statistic for the hypothesis test that forces all the coefficients to zero is generated using the ANALYZ procedure in TSP.

AR(1) Test and Estimation

The test for AR(1) in the DFAM model is accomplished using the likelihood ratio (LR) test where the DFAM with AR(1) imposed is the unrestricted model and the DFAM without AR(1) is the restricted model. In this study, the estimate of the autocorrelation parameter ρ will be obtained using full maximum likelihood estimation where ρ will be common across equations. This procedure is found in Berndt and Savin (1975), Green et al. (1978) and Beach and MacKinnon (1979). The test for autocorrelation will be performed using the likelihood ratio test. In this procedure the DFAM model will be estimated with and without AR(1) disturbances. The likelihood ratio test will then be used to test the hypothesis $\rho = 0$, where the DFAM with non-autocorrelated disturbances will be the restricted model. If autocorrelation can not be rejected, then the autocorrelated DFAM will be used to test for economic properties and forecasting.

Testing Economic Theory

The DFAM allows for homogeneity, symmetry, and negative semi-definiteness to be tested, imposed, or checked. The homogeneity property is satisfied when $\sum_j \pi_{ij} = 0$, which implies that $\pi_{in} = -\pi_{i1} - \pi_{i2} - \cdots - \pi_{in-1}$. Imposing this restriction on equation (5.1) yields (Theil, 1971)

$$\bar{f}_{it} D_{it} = \theta_i DX_t + \sum_{j=1}^{n-1} \pi_{ij} \; (Dw_{jt} - Dw_{nt}) + \varepsilon_{it} . \tag{5.3}$$

Equation (5.3) will be estimated using the LSQ procedure in TSP. The resulting log likelihood value will be obtained from the estimation procedure and used in a LR test to determine if the homogeneity constraint is valid. For this test the homogeneity constrained model is the restricted model which will be compared to the unconstrained system. If homogeneity is rejected, then Laitinen's exact test for homogeneity will be used.

The symmetry constrained ML estimator can be obtained using the LSQ procedure in TSP as well. This is accomplished by first imposing homogeneity and then restricting the symmetric parameters equal. For example, the *ith* price coefficient in the *jth* equation will be restricted to equal the *jth* price coefficient in the *ith* equation. Once these restrictions are imposed, estimates are obtained using the LSQ procedure. The log likelihood value of this estimation will be used to verify the symmetry property, where the symmetry constrained system is the restricted model and the homogeneity constrained system is the unrestricted model.

The property of negative semi-definiteness is verified by inspection of the eigenvalues of the price coefficient matrix. This property is verified when all of the eigenvalues are less than or equal to zero. If any values are questionable, judgement will be made based on the standard errors of the price coefficient estimates.

Mean –based elasticities will be calculated using the constrained parameters in equation (5.1) resulting from the estimation procedure. These elasticities are as follows.

$$\varepsilon_{xw} = \frac{Dx_i}{Dw_j} = \frac{\pi_{ij}}{f_i}. \tag{5.4a}$$

Equation (5.4a) is the conditional own and cross price elasticity. This will be evaluated at the mean factor share. Equation (5.4a) is the percentage change in the quantity demanded of an imported dairy product from the *ith* source country resulting from a 1 percent change in the price of that same product from source country *j*.

$$\varepsilon_{xX} = \frac{Dx_i}{DX} = \frac{\theta_i}{f_i}. \tag{5.4b}$$

Equation (5.4b) is the Divisa index elasticity, which reflects the effects of a change in the Divisa index on imports from the various source countries. Given that this index is proportional to total imports, this elasticity reflects the effects of total import changes on source-specific imports.

$$\varepsilon_{xw}^{A} = \frac{\pi_{ij}}{f_i f_j}, \quad i \neq j. \tag{5.4c}$$

Equation (5.4c) is the Allen-Uzawa elasticity of substitution, which measures the substitutability of inputs in a production process. This elasticity is similar to the conditional cross-price elasticity in derivation.

Forecasting and Simulation Procedure

Objectives of this study are to project future derived demand for dairy products in the selected international markets, and to simulate the effects of trade liberalization. Given the left-hand side of equation (5.1), quantity forecasts are not easily obtained. In chapter 4, two methods were presented as a means of obtaining quantity forecasts with the DFAM. The first approach is a model-based approach, which uses the estimated model as a mean of forecasting future quantities. The model-based forecasting equation for the DFAM is

$$x_{it} = \exp\left[\frac{\theta_i DX_t + \sum_{j=1}^{n} \pi_{ij} (\log w_{it} - \log w_{it-1})}{\dfrac{\dfrac{w_{it} x_{it}}{\sum_{i=1}^{n} w_{it} x_{it}} + \dfrac{w_{it-1} x_{it-1}}{\sum_{i=1}^{n} w_{it-1} x_{it-1}}}{2}} + \log x_{it-1} \right]. \tag{5.5}$$

Use of equation (5.5) requires that the Divisa index and prices are exogenous, where the only unknowns are the individual quantities. Given prices, the Divisa index, and all lag values, equation (5.5) results in a system of i equations with i unknowns which can be solved for the x's using the SOLVE procedure in TSP. This procedure uses a Gauss-Seidel algorithm.

The second method is the elasticity based approached, similar to the approach used by Kastens and Brester (1996). The elasticity-based forecasting equation for the DFAM is

$$x_{i,t} = \left(\sum_{j=1}^{n} \varepsilon_{ij} \left[\frac{w_{jt} - w_{jt-1}}{w_{jt-1}} \right] + \varepsilon_i \left[DX_t \right] \right) x_{it-1} + x_{it-1} \tag{5.6}$$

where ε_{ij} and ε_i are the price and Divisa elasticity respectively evaluated at the mean. Both procedures will use results from the estimation procedure where the economic properties of homogeneity and symmetry are imposed. Kastens and Brester (1996) suggest that forecast should be theoretically constrained even when the data rejects the constraints. They found that theoretical constraints greatly improved the precision of the forecast estimates. This will be tested in this study when the theoretical properties are rejected.

The first step in the forecasting and simulation procedure is to determine which of the two approaches is most accurate in terms of forecasting. To determine which method is best, each of the DFAM systems are estimated using all except the last 3 to 5 years of the data sets. Using both model-based and elasticity-based forecasting methods to forecast the remaining years, the precision of each of these methods determined which of the two procedures to use in forecasting and simulating future periods. When economic properties are rejected, the remaining years are also forecasted using both the mean-base and elasticity-base approach for the unrestricted model. The result is four forecasting options: elasticity-based no restrictions, elasticity-based constrained, model-based no restriction, and model-based constrained. All four outcomes are compared to determine which is best at forecasting the remaining years. This is done to test the results in Kastens and Brester (1996), which indicated that forecast were improved when parameters were theoretically constrained, even when constraints were rejected by the data.

Imported quantities of individual dairy products are projected until the year 2003 using the better of the two forecasting procedures. The exogenous variables, the Divisa index and prices, are set to 5-year growth rates (1994-1998). The Divisa index from 1999 to 2003 is set equal to the average Divisa index for the period 1994 to 1998. Setting the Divisa index to this value maintains the average growth in the quantity imported for the last 5 years. Prices in the forecasting period are set equal to last year prices times the 5 year average growth rate. This procedure determines the growth in imports from each individual source if trends continue.

Future imported quantities of imported dairy products resulting from trade liberalization are simulated until the year 2003, which is the first half of the new World Trade Organization (WTO) implementation period. The policy that will be investigated is the further reduction in export subsidies permitted to the EU. Although the U.S. subsidizes dairy exports, subsidized exports to Asian countries overall have been negligible. For Mexico, subsidy reductions for both the U.S. and the EU are considered.

In order to assess the effects of subsidy reductions on the quantity of imported dairy products demanded by a given country, we must first know how subsidy reductions affect the price that an individual exporting country charges. Since export subsidies are a policy exclusive to the exporting country, the importing country only realizes a lower price for the products exported under subsidy. Figure 5-1 is an example of the effects of EU subsidy reductions in the EU-cheese market. Since we are assuming that imported products are differentiated by country of origin, we can view the EU-cheese market as a separate market when analyzing the effects of export subsidy changes. When subsidies are reduced from SUB^1 to SUB^2, this results in a fall in the total exported (EX^1 to EX^2), thereby increasing the world price of EU-cheese (Pw^1 to Pw^2). The increase in the world price is the only change realized in the Japanese market for EU-cheese. The result is a decrease in the quantity of EU-cheese imported (IM^1 to IM^2). This analysis indicates that a reduction in export subsidies can be simulated in the DFAM by increasing the price of the subsidized commodity. However, what is still needed is the effect of a subsidy reduction on prices. Gardner (1987) shows that the elasticity of demand price with respect to a 1 percent change in a producer subsidy payment is

$$\frac{\%\Delta P}{\%\Delta V} = \frac{-1}{1-\eta/\varepsilon} \tag{5.7}$$

where P is the demand price, V is the subsidy payment, η and ε are the own price demand and supply elasticity respectively. Applying equation (5.7) to export subsidies, it becomes the percentage change in the world price of the subsidized product resulting from a 1 percent change in export subsidy payments. The resulting

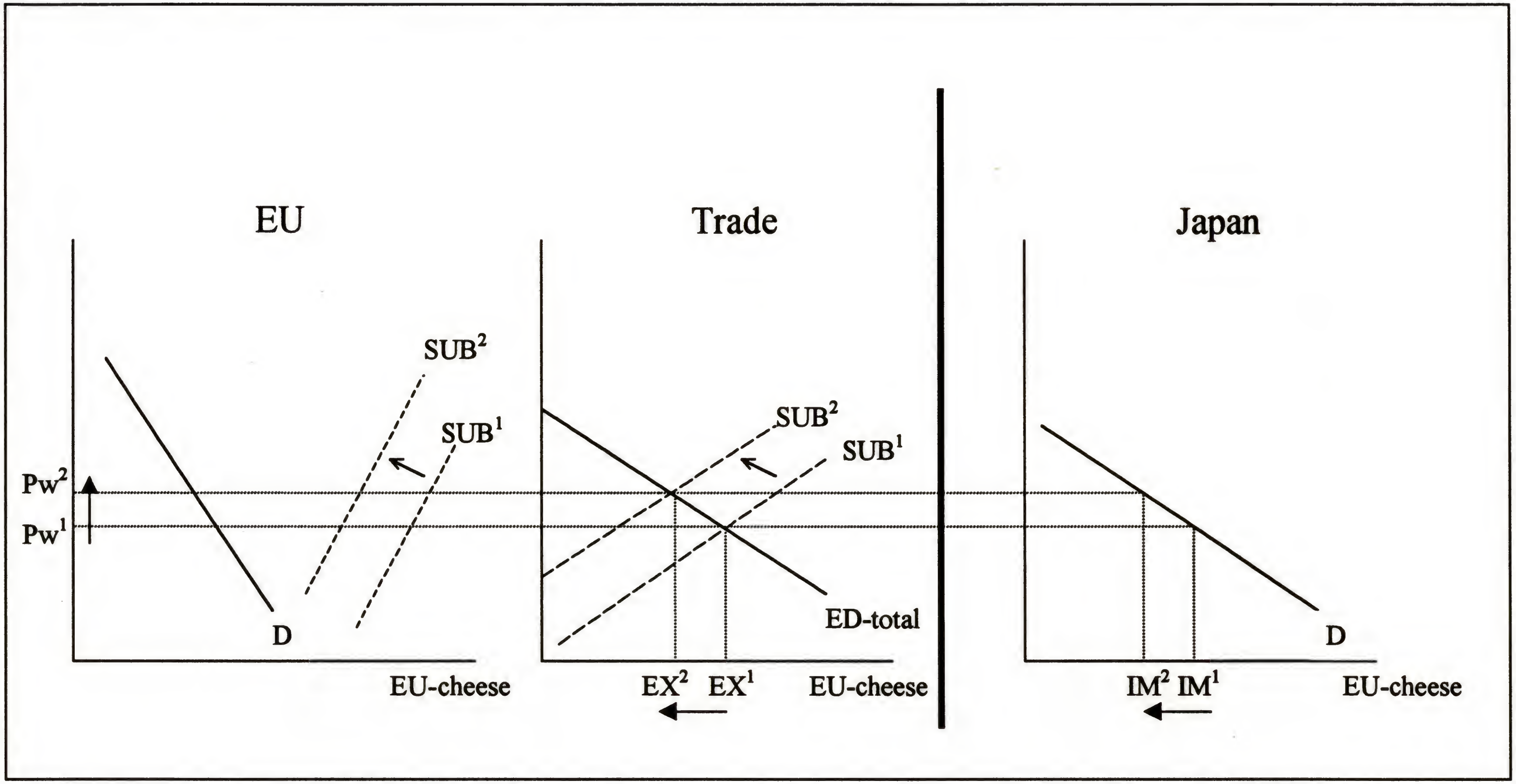

Figure 5-1 Effects of EU subsidy reductions on Japan's imports market for EU-cheese

change in price will then be used in either of the two forecasting procedures to assess the changes in import demand.

Data

The Commodity Trade Statistics section of the United Nations provided the data used in this study. For each importing country (Hong Kong, Japan, and Mexico), imported quantities in metric tons and value in $1000US of total imports, imports from the U.S., Australia, New Zealand, and the EU for each of the dairy products (butter, cheese, dry milk, and whey) were obtained. The time period for all of the data sets, except whey, was from 1962 to 1998. All whey data sets were from 1976 to 1998. The value of imports was on a cost, insurance, and freight (CIF) basis, which include the cost of the product, the insurance paid, and the transportation cost. Commodity prices were calculated by dividing the value of the commodity imported by the quantity, which results in a per-unit cost per kilogram measure. The rest of the world quantities and values were calculated by subtracting the total quantity and value imported from the U.S., Australia, New Zealand, and the EU from the overall total imported quantity and value respectively.

CHAPTER 6
EMPIRICAL RESULTS

Estimation of the differential factor allocation model (DFAM) requires that the first log difference be taken with respects to prices and quantities. Data sets used for estimation can not have any missing values or zeros because the log of zero is undefined. Due to a number of data sets having quantities unreported for a number of years, only 5 out of 12 estimations were performed. These were the derived demand for imported cheese in Hong Kong, imported dry milk in Hong Kong, imported cheese in Japan, imported whey in Japan, and imported butter in Mexico. Of these five, all estimations except for Japan's derived demand for imported cheese, required that data for Australia and New Zealand be aggregated. This was due to missing observations for both countries for different years. When aggregated they form a complete data set. The aggregation of these two countries is referred to as Oceania.[1]

The first step in the estimation procedure was to test for the presence of autocorrelation in each of the systems. Since estimation of the DFAM requires that we take the first difference of the log of the variables, this is often a correction for autocorrelation; however, autocorrelation may still exist. Likelihood ratio (LR) tests were used to test for the presence of AR(1) in the 5 estimated systems. These tests

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[1] For the Australia and New Zealand aggregation it was assumed that missing observations were either zero or small.

Table 6-1 Likelihood ratio test results for autocorrelation

Country/Product	Model	Log-likelihood Value	LR*	$P[\chi^2_{(j)} \leq LR^*]=.95$
Hong Kong-Cheese	AR(1)	213.946		
	No-AR(1)	211.942	3.9461	3.84(1)[a]
Hong Kong-Dry Milk	AR(1)	148.474		
	No-AR(1)	147.627	1.6962	
Japan-Cheese	AR(1)	367.369		
	No-AR(1)	367.369	.0000	
Japan-Whey	AR(1)	55.125		
	No-AR(1)	48.729	12.7927	
Mexico-Butter	AR(1)	47.130		
	No-AR(1)	45.896	2.4685	

[a] The number of restrictions are in parenthesis.

required that the DFAM be estimated with and without AR(1) disturbances where the autocorrelated version of the DFAM was the unrestricted model and the DFAM without autocorrelation was the restricted model.

Table 6-1 presents the log-likelihood values, the LR statistics, and the critical value for the LR test for autocorrelation for each system. Of the systems estimated, the Hong Kong-cheese and Japan-whey models were the only models where the hypothesis of no autocorrelation was rejected by at least the .05 significance level. Results for all other models indicate that the null hypothesis of no autocorrelation could not be rejected.

In addition to autocorrelation, LR tests were also used to test if the data satisfied the economic properties, homogeneity and symmetry. The results of these

Table 6-2 Likelihood ratio test results for economic constraints and Laitinen's test for homogeneity

Country/Product	Model	Log-likelihood Value	LR*	$P[\chi^2_{(j)} \leq LR^*]=.95$
Hong Kong Cheese	Unrestricted	213.825		
	Homogeneity	212.172	3.306	7.81(3)[a]
	Symmetry	210.814	2.715	7.81(3)
Hong Kong Dry Milk	Unrestricted	147.627		
	Homogeneity	145.434	4.387	7.81(3)
	Symmetry	144.725	1.417	7.81(3)
Japan Cheese	Unrestricted	367.369		
	Homogeneity	362.395	9.948	9.49(4)
	Symmetry	356.428	11.934	12.60(6)
Japan Whey	Unrestricted	54.683		
	Homogeneity	49.304	10.758	7.81(3)
	Symmetry	46.200	6.207	7.81(3)
Mexico Butter	Unrestricted	45.896		
	Homogeneity	43.809	4.174	7.81(3)
	Symmetry	42.546	2.526	7.81(3)
		Laitinen's Test		
		W*[b]	$P[T^2 \leq W^*]=.95$[c]	
Japan Cheese	Homogeneity	4.027	12.133	
Japan Whey	Homogeneity	9.217	11.186	

[a] The number of restrictions are in parenthesis.

[b] W* is the Wald statistic for the homogeneity constraint.

[c] T^2 is the Hotelling's T^2 statistic.

tests are summarized in Table 6-2. LR tests indicate that the property of homogeneity could not be rejected in any of the systems except Japan-cheese and Japan-whey. In both instances, homogeneity was rejected by at least the .05 significance level. However, Laitinen's test for homogeneity, which is a more precise test, indicated that homogeneity could not be rejected in the Japan-cheese and Japan whey systems.

Given the homogeneity constraint, symmetry could not be rejected in any of the estimated systems at the .05 significance level.

The property of negative semidefiniteness was verified by inspection of the eigen values of the price coefficient matrix. This property is validated when all of the eigen values are less than or equal to zero. All eigen values were non-positive in only two of the five systems. These are Hong Kong-cheese and Japan-whey. The price coefficient matrix for the remaining systems contained only one eigen value that was positive and in most cases this was a small number. Eigen values that had zeros up to the fifth decimal place were considered to be zero.

Overall, the properties of homogeneity and symmetry could not be rejected for all of the systems estimated. This indicates that the data used reflect that firms behave in an optimal manner. However, the eigen values for all of the price coefficient matrices indicated that only two matrices were negative semidefinite. This is the result of insignificant price coefficients.

Empirical Results for Hong Kong

Since homogeneity and symmetry could not be rejected for any of the Hong Kong systems, all results that are reported in this section have homogeneity and symmetry imposed. Also, results for the Hong Kong-cheese system has AR(1) imposed as well. Table 6-3 presents the parameter estimates for Hong Kong's derived demand for imported cheese. Since symmetry is imposed, the lower triangular portion of the price coefficient matrix is exactly equal to upper triangular portion, and is therefore left blank.

Table 6-3 DFAM parameter estimates for Hong Kong imports of cheese

Exporting Country	Price Coefficients, π_{ij}				Marginal Factor Shares, θ_i
	U.S.	Oceania[a]	EU	ROW[b]	
U.S.	-.1040 (.0131)[c]***	.0217 (.0265)	.0512 (.0263)*	.0311 (.0185)*	.0864 (.0251)***
Oceania		-.1446 (.0874)*	.1844 (.0774)**	.-0615 (.0485)	.4823 (.0645)***
EU			-.3192 (.1026)**	.0836 (.0579)	.3597 (.0647)***
ROW				-.0533 (.0536)	.0716 (.0390)*

System $R^2 = .91$

[a] Australia and New Zealand aggregation.
[b] ROW= rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significant level = .01
** Significant level = .05
* Significant level = .10

The marginal share (θ_i) coefficients for each equation in the system are all significant at any reasonable significance level. The marginal shares are also all positive, indicating that as total imports grow, imports from the individual exporting countries grow as well. All own-price coefficients are negative, which is to be expected, and with the exception of the ROW, the own-price coefficients are all significant by at least the .10 significance level. With the exception of the Oceania/ROW cross-price coefficient, all cross-price coefficients are positive, indicating that these goods are for the most part substitutes. The negative cross-price coefficient for Oceania and the ROW indicate a possible complementary relationship

Table 6-4 DFAM parameter estimates for Hong Kong imports of dry milk

	Price Coefficients, π_{ij}				Marginal Factor
Exporting Country	U.S.	Oceania[a]	EU	ROW[b]	Shares, θ_i
U.S.	-.0605	.0388	-.0033	.0249	.1604
	(.0282)[c]**	(.0328)	(.0277)	(.0230)	(.0448)***
Oceania		.0252	.0131	-.0771	.3605
		(.0845)	(.0550)	(.0544)	(.0602)***
EU			.0007	-.0104	.4641
			(.0548)	(.0362)	(.0504)***
ROW				.0626	.0150
				(.0511)	(.0413)
System R^2 = .88					

[a] Australia and New Zealand aggregation.
[b] ROW= rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significant level = .01
** Significant level = .05

between the imports from these two sources. This may be due to the fact that the more generic brands of cheese are from these sources and these types of cheeses may be purchased together. These goods may also be independent given that the parameter estimate is not statistically different from zero. Of the cross-price coefficients, three were significant. These are the U.S./EU, U.S./ROW and the Oceania/EU cross-price coefficients. All indicate that goods from these sources are substitutes (Table 6-3).

Parameter estimates for Hong Kong's derived demand for imported dry milk is presented in Table 6-4. Similar to the derived demand for cheese, the marginal factor shares are positive and are highly significant at any reasonable significance level (ROW excluded). The own price coefficients for the U.S. was the only price coefficient with the correct sign, and it was the only significant price coefficient. All other own-price coefficients are not significantly different from zero. The cross-price parameter estimates are not significantly different from zero as well. (Table 6-4) These results indicate that Hong Kong's derived demand for U.S. dry milk depends on both the product cost and the total quantity imported; however, imports from Oceania and the EU are determine by the total import decision only.

One possible reason for EU and Oceania price coefficients insignificance and the U.S. significance is that the price (per unit cost per kilogram (kg)) for U.S. dry milk in Hong Kong has been significantly higher than EU and Oceania prices for quite some time. Figure 6-1 shows the prices for dry milk in Hong Kong charged by the exporting sources from 1962 to 1998. The U.S. dry milk price in Hong Kong has been higher than all other import prices since mid 1970. Since that time prices have been twice the price of all other sources and nearly three times Oceania prices in early 1990. From 1962 until the latter part of 1980, there has been little difference in Oceania and EU prices. Relatively high U.S. prices and little difference in EU and Oceania prices may be a possible reason why total imports were a much more determining factor than price for these two sources.

Table 6-5 presents the Divisia import and conditional own and cross-price elasticities for Hong Kong's derived demand for imported cheese. The Divisia import elasticities for the U.S., Oceania, EU, and the ROW are 1.284, 1.013, 1.196, and .459 respectively. Of these elasticities, all are significant by at least the .10 significance level. The Divisia import elasticity is somewhat similar to a total import elasticity, which would indicate the percentage change in imports from the exporting countries

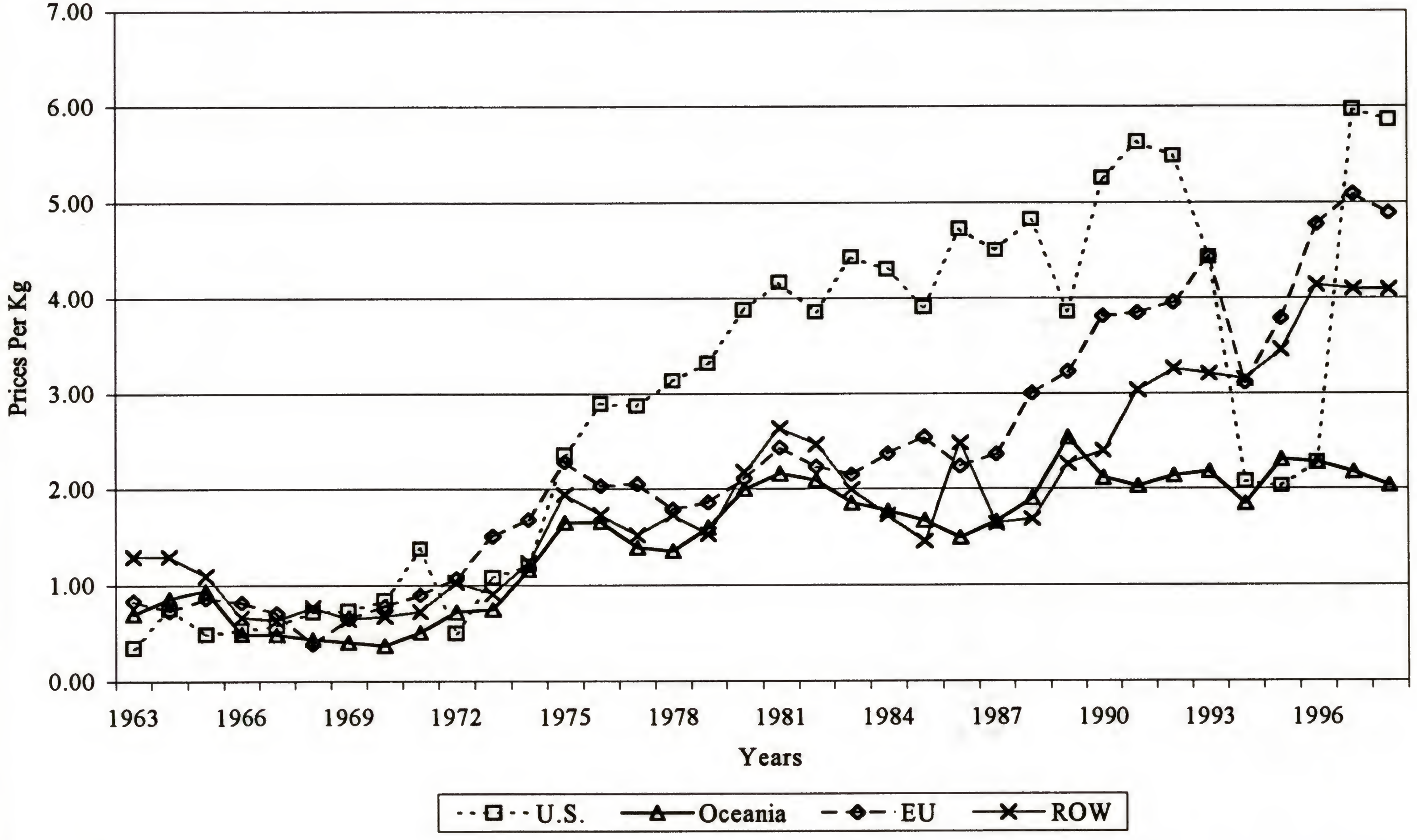

Figure 6-1 Hong Kong dry milk import prices: 1962-1998

Table 6-5 Hong Kong Divisia and price elasticities of the derived demand for imported cheese

Exporting Country	Elasticities					
	Divisia Import	Conditional Own-Price	Conditional Cross-Price			
			U.S.	Oceania[a]	EU	ROW[b]
U.S.	*1.284*[c]	*-1.546*		.323	*.761*	*.462*
	(.373)[c]	(.195)		(.393)	(.391)	(.274)
Oceania	*1.013*	*-.304*	.046		*.387*	-.129
	(.136)	(.183)	(.056)		(.163)	(.102)
EU	*1.196*	*-1.061*	*.170*	*.613*		.278
	(.215)	(.339)	(.087)	(.257)		(.192)
ROW	*.459*	-.342	*.200*	-.394	.537	
	(.250)	(.344)	(.118)	(.311)	(.372)	

[a] Australia and New Zealand aggregation.

[b] ROW = rest of the world.

[c] *Italics* indicate that the elasticity was significant by at least .10.

[c] Asymptotic standard errors are in parentheses.

given a percentage change in total imports. Given that the Divisia index is proportional to a percentage change in the total quantity imported, the Divisia elasticity indicates a similar relationship as the total import elasticity. Of all the Divisia elasticities, the U.S. elasticity is the largest. This indicates that as total imports of cheese into Hong Kong increase such that the Divisia index increases, U.S. cheese imports into Hong Kong should increases by a larger percent when compared to the increase in imports from other exporting sources. However, with the exception of the ROW, these elasticities are not significantly different from 1. This indicates that as total imports of cheese increase in Hong Kong, imports from the primary sources should increase by the same percent as total imports.

The own-price elasticities of Hong Kong's derived demand for imported cheese from the U.S., Oceania, EU and the ROW are –1.546, -.304, -1.061 and -.342 respectively. Except for the ROW all own-price elasticities are significant at the .10 significance level. Elasticities indicate that the derived demand for U.S. and EU cheese in Hong Kong is highly elastic, with the demand for U.S. cheese being the most elastic of all the exporting sources. The derived demand for Oceania cheese is inelastic, indicating that cheese from Oceania imported into Hong Kong is less responsive to price changes than imports from other sources.

The inelastic demand for Oceania cheese may be due to their prices being less than all other prices from competing sources. Figure 6-2 shows the prices of cheese in Hong Kong from 1962 to 1998. Oceania prices since 1962 have been consistently lower than all other prices. As prices increased, they were still the cheapest source for imported cheese in Hong Kong. Since imports from alternative sources was still relatively more expensive, demand may have been somewhat less responsive when compared to the demand for cheese from other sources.

Cross-price elasticities indicate a substitutional relationship between exporting sources for cheese imports into Hong Kong. The cross-price elasticity that stands out is the U.S.-EU elasticity, which says that if the price of EU cheese increase by 1 percent, the quantity demanded for U.S. cheese will increase by .761 percent. The Oceania-EU cross-price elasticity indicates that imports from Oceania will increase by .387 percent. This suggests that the U.S. stand to benefit more than Oceania percentage wise when EU dairy export subsidy reductions lead to increases in the EU cheese price (Table 6-5).

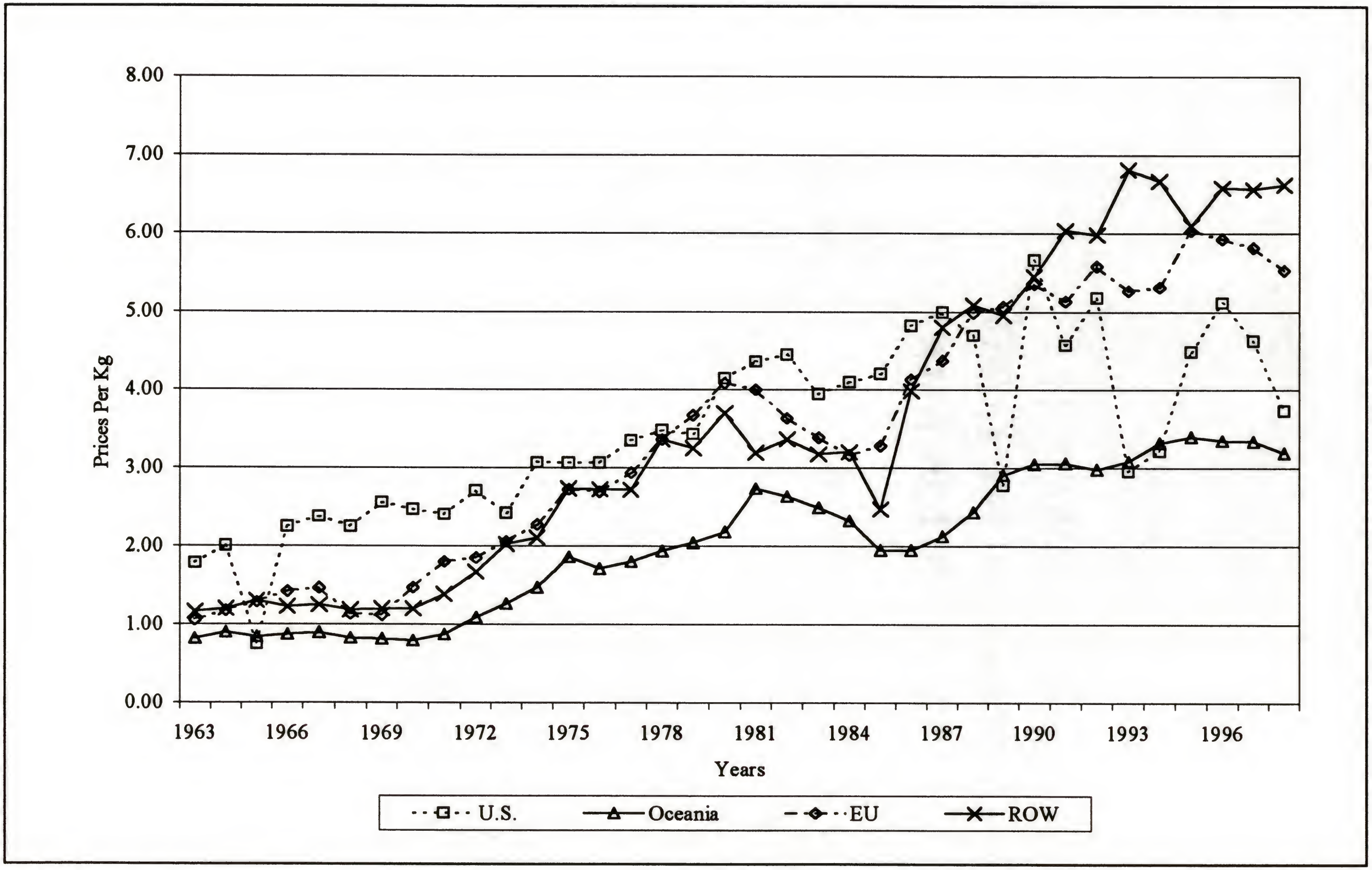

Figure 6-2 Hong Kong cheese import prices: 1962-1998

Table 6-6 Hong Kong Divisia and price elasticities of the derived demand for imported dry milk

		Elasticities				
Exporting Country	Divisia Import	Conditional Own-Price	Conditional Cross-Price			
			U.S.	Oceania[a]	EU	ROW[b]
U.S.	*1.268*[c]	*-.478*		.307	-.026	.197
	(.354)[c]	(.223)		(.260)	(.219)	(.181)
Oceania	*.952*	.067	.103		.035	-.204
	(.159)	(.223)	(.087)		(.145)	(.144)
EU	*1.349*	.002	-.010	.038		-.030
	(.147)	(.159)	(.081)	(.160)		(.152)
ROW	.099	.414	.166	-.511	-.069	
	(.274)	(.338)	(.152)	(.360)	(.240)	

[a] Australia and New Zealand aggregation.

[b] ROW = rest of the world.

[c] *Italics* indicate that the elasticity was significant by at least .10.

[c] Asymptotic standard errors are in parentheses.

Table 6-6 presents the Divisia and conditional own and cross-price elasticities for Hong Kong's derived demand for imported dry milk. The Divisia import elasticity for the U.S., Oceania, EU, and the ROW are 1.268, 0.952, 1.349 and 0.099 respectively. These indicate that as total imports of dry milk increase in Hong Kong, imports from the EU and the U.S. should increase by a greater percentage than imports from Oceania and the ROW.

All of the conditional own-price elasticities for imports of dry milk into Hong Kong were not significantly different from zero, except the own-price elasticity for U.S. dry milk, which is -0.478. This may also be due to relative high U.S. prices and EU and Oceania prices being relatively close together (Figure 6-1).

Table 6-7 Allen-Uzawa partial elasticities of import substitution

Exporting Country	Cheese			
	U.S.	Oceania[a]	EU	ROW[b]
U.S.		.677	*2.530*[c]	*2.971*
		(.826)[d]	(1.300)	(1.761)
Oceania			*1.288*	-.829
			(.541)	(.653)
EU				1.785
				(1.235)
ROW				
	Dry Milk			
U.S.		.810	-.077	1.308
		(.685)	(.636)	(1.202)
Oceania			.101	-1.350
			(.422)	(.950)
EU				-.201
				(.697)
ROW				

[a] Australia and New Zealand aggregation.

[b] ROW = rest of the world.

[c] *Italics* indicate that the elasticity was significant by at least .10.

[d] Asymptotic standard errors are in parentheses.

There is no cross-price elasticity that was significantly different from zero, indicating very little substitution between dry milk imported from the various sources (Table 6-6). This may be due to the relationship among prices as well. Recall that in Figure 6-1, Oceania, EU, and ROW prices were very close together for most of the observation period. As a result, substitution between imports from the source countries due to price changes may be small.

The Allen-Uzawa partial elasticities of substitution for both models are presented in Table 6-7. Since these elasticities are symmetric the lower triangular portion of the elasticity matrix is left blank. The elasticity of substitution between U.S. and EU cheese, U.S. and ROW cheese and the substitution elasticity between Oceania and EU cheese are the only elasticities in the Hong Kong cheese system that are significant by at least the .10 significance level. These elasticities are 2.530 for the U.S./EU, 2.971 for U.S./ROW, and 1.288 for Oceania/EU. This indicates that for a desired output, U.S. cheese is more suitable than Oceania cheese in substituting for EU cheese and ROW and vice versa. This may be due to the U.S. and the EU being high quality cheese producers while Oceania tend to be the generic brand cheese producers (Zhou and Novakovic, 1996).

Very little can be said about the Allen-Uzawa partial elasticities of substitution for imported dry milk. Results indicated that all of the substitution elasticities for the system are not significantly different from zero at any reasonable significance level.

Hong Kong's derived demand system for imported cheese was re-estimated using all of the available years except the last five (1994-1998). Once new estimates were obtained, equations (5.5) and (5.6), which are the model-based and elasticity based forecasting equations respectively, were used to forecast imported quantities for the remaining years. This was done to determine which of the two equations forecasted with the most precision. Precision of forecasts was determined by the absolute percentage difference in the forecasted and actual quantities. Table 6-8 presents the absolute percentage difference in the actual and forecasted values. Results show that the forecasting precision of the elasticity-based approach was a 14 percent improvement over model-based forecasts on average. For each country, forecasts

Table 6-8 Percentage differences in the actual quantities and forecasts for Hong Kong cheese imports: 1994-1998

Year	U.S.	Oceania[a]	EU	ROW[b]	Overall Average
Model-Based Forecasts					
		Percent			
1994	45.8	6.3	4.5	12.0	
1995	58.1	11.0	1.2	25.6	
1996	29.1	16.0	16.4	25.7	
1997	23.9	16.8	7.4	115.5	
1998	53.1	16.2	12.0	124.3	
Average	42.0	13.2	8.3	60.6	31.0
Elasticity-Based Forecasts					
1994	23.7	1.4	5.8	21.2	
1995	11.6	1.6	2.1	10.0	
1996	18.8	6.4	18.9	16.9	
1997	40.7	3.1	9.4	27.8	
1998	62.7	0.6	18.7	31.9	
Average	31.5	2.6	11.0	21.5	16.7

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

improved by as much as 39 percent when using elasticities instead of the model to forecasts.

The Hong Kong dry milk system was re-estimated using all observations up until the last three years and forecast were done for the remaining years (1996-98). Due to convergence problems with the model-base approach, 3 instead of 5 years were forecasted. Forecast results for Hong Kong dry milk imports indicate that the

Table 6-9 Percentage differences in the actual quantities and forecasts for Hong Kong dry milk imports: 1996-1998

Year	U.S.	Oceania[a]	EU	ROW[b]	Overall Average
Model-Based Forecasts					
		Percent			
1996	52.82	57.61	37.66	25.56	
1997	99.88	54.90	47.79	52.69	
1998	100.00	61.50	57.15	25.99	
Average	84.23	58.00	47.54	34.75	56.13
Elasticity-Based Forecasts					
1996	35.43	52.87	38.69	27.65	
1997	89.13	54.09	47.09	75.97	
1998	85.42	52.45	45.12	46.08	
Average	69.99	53.14	43.63	49.90	54.17

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

elasticity approach performed better than the model-based approach for this system. Overall improvements in forecasts were on average about 2 percent. Forecast for the U.S, Oceania, and the EU, improved by as much as 14 percent when using elasticity-based forecasts (Table 6-9). Given the performance of elasticity approach, it was used for the remaining forecasts and simulations in this section.

Simulations for the period 1999 to 2003 were accomplished using 1994-98 average growth in prices. 1999-2003 prices were then obtained by setting prices in the current period equivalent to last years prices times the growth rate. Values for the Divisia index in the future period were set to the 1994-98 Divisia index average.

Table 6-10 Hong Kong cheese imports based on 5-year averages: 1999-2003

Year	U.S.	Oceania[a]	EU	ROW[b]
	Metric tons			
1999	734.83	5,605.23	1,529.98	134.27
2000	729.69	6,021.20	1,657.83	140.85
2001	724.59	6,468.04	1,796.35	147.74
2002	719.52	6,948.03	1,946.45	154.98
2003	714.49	7,463.65	2,109.10	162.57

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

Table 6-10 shows the expected imported quantities of cheese into Hong Kong from each of the source exporters. The 5-year average growth was used to project prices for the period 1999 to 2003. The growth rates for the U.S., Oceania, EU and the ROW respectively was 6.7, .78, 1.1 and -0.42 percent. The 1994-98 Divisia index average was .06763. Simulations indicate that if trends continue the quantity of U.S. cheese imported into Hong Kong will decrease from 735 metric tons to 714 metric tons by 2003. This decrease is due to the large percentage increase in cheese prices over shadowing the effects of increased imports. If trends continue, imports from all other sources should increase. Hong Kong cheese imports from Oceania is expected to increase from 5,605 metric tons to 7,464 metric tons by 2003, for an increase of about 2,000 metric tons. Imports from the EU are expected to increase from 1,530 metric tons to 2,109 metric tons. Imports from all other sources are expected to increase by 29 metric tons.

Table 6-11 Hong Kong dry milk imports based on 5-year averages: 1999-2003

	U.S.	Oceania[a]	EU	ROW[b]
Year		*Metric tons*		
1999	2,069.26	36,297.36	21,113.46	10,351.12
2000	2,266.72	39,442.51	23,744.44	10,787.94
2001	2,483.02	42,860.19	26,703.28	11,243.18
2002	2,719.96	46,574.00	30,030.82	11,717.64
2003	2,979.51	50,609.62	33,773.01	12,212.11

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

Simulations based on 5-years trends were done for imports of dry milk into Hong Kong as well. The five-year average growth in dry milk prices for the U.S., Oceania, EU, and the ROW was 6.6, -0.5, 4.2, and 5.3 percent respectively. The 1994-98 Divisia index average was .09104. These values were used to generate data for the period 1999 to 2003.

Projections for the period 1999 to 2003 indicate that if trends continue, imports of U.S. dry milk into Hong Kong will increase by 910 metric tons to a total of 2,980 metric tons by the year 2003. Imports from Oceania will increase by over 14,000 metric tons to 50,610 metric tons, and imports from the EU will increase by over 12,500 metric tons to 33,773 metric tons by the year 2003. Imports from all other sources are expected to increase by 1,900 metric tons to 12,212 metric tons. In forecasts for both cheese and dry milk, if trends continue imports from Oceania is expected to increase more so than imports from all other sources.

Out of commitment to the Uruguay Round (UR) General Agreement on Tariffs and Trade (GATT), the EU has agreed to reduce export subsidy expenditures by 36 percent during the period 1995 to 2000. The question thus arises, how will import quantities change given the continuation of this policy or that new trade policy is more aggressive.

Equation (5.7) was used to assess the percentage change in demand price resulting from a percentage change in a producer subsidy payment. Zhou et al. (1998) indicates that the own-price supply elasticity for the EU is .65 for all milk produced and the own-price demand elasticity for cheese and dry milk is -0.40. Using these elasticities in equation (5.7), the elasticity of the cheese and dry milk demand price with respect to a subsidy payment are both -0.619. A 36 percent reduction over a six-year period is a 6 percent per year reduction on average. Using -0.619, a 6 percent subsidy reduction results in a 3.7 percent increase in the demand price per year. A 72 percent subsidy reduction over a six-year period results in a 7.43 percent per year increase in the demand price. These percentages are use to simulate the effects of EU subsidy reductions at the current rate and twice the current rate. Since the UR GATT implementation period ends the year 2000, the 72 percent reduction is applied to the period 2001 to 2003.

Table 6-12 presents the expected quantities of cheese imported into Hong Kong if the upcoming World Trade Organization (WTO) agreement continues subsidy reduction at the current rate or twice the rate of the UR GATT agreement. If reductions continue at the same pace, imports of U.S. cheese into Hong Kong for the period 1999 to 2003 are expected to increase from 761 to 850 metrics. Imports from

Table 6-12 Hong Kong cheese imports given a 36 and 72 percent EU export subsidy reduction: 1999-2003

Year	U.S.	Oceania[a]	EU	ROW[b]
		36% Subsidy Reduction: 1999-03 *Metric tons*		
1999	760.91	5,293.04	1,356.34	130.55
2000	782.41	5,369.17	1,302.87	133.16
2001	804.52	5,446.39	1,251.51	135.81
2002	827.26	5,524.72	1,202.18	138.52
2003	850.64	5,604.17	1,154.79	141.28
		36% Subsidy Reduction: 1999-00 72% Subsidy Reduction: 2001-03		
1999	760.91	5,293.04	1,356.34	130.55
2000	782.41	5,369.17	1,302.87	133.16
2001	826.63	5,523.61	1,200.15	138.47
2002	873.35	5,682.48	1,105.53	143.99
2003	922.71	5,845.93	1,018.37	149.73

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

Oceania are expected to increase from 5,293 to 5,604 metric tons for an overall increase of 311 metric tons. Imports from the EU are expected to decrease by 201 metric tons. Imports from all other sources are expected to increase by 11 metric tons. If subsidy reductions for the WTO agreement are twice the UR GATT rate, imports from the U.S. for the same period is expected to increase from 761 to 923 metric tons, an increase of 162 metric tons. Imports from Oceania are expected to increase to 5,846 metric tons, an increase of 553 metric tons. Imports from the EU will be down

Table 6-13 Hong Kong dry milk imports given a 36 and 72 percent EU export subsidy reduction: 1999-2003

Year	U.S.	Oceania[a]	EU	ROW[b]
		36% Subsidy Reduction:1999-03 *Metric tons*		
1999	1,887.15	33,445.94	18,775.34	9,906.54
2000	1,885.30	33,488.94	18,776.68	9,881.14
2001	1,883.45	33,531.99	18,778.02	9,855.81
2002	1,881.60	33,575.10	18,779.37	9,830.54
2003	1,879.76	33,618.27	18,780.71	9,805.34
		36% Subsidy Reduction:1999-00 72% Subsidy Reduction:2001-03		
1999	1,887.15	33,445.94	18,775.34	9,906.54
2000	1,885.30	33,488.94	18,776.68	9,881.14
2001	1,881.60	33,575.05	18,779.37	9,830.48
2002	1,877.91	33,661.37	18,782.05	9,780.07
2003	1,874.23	33,747.92	18,784.73	9,729.93

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

by over 300 metric tons. Imports from all other sources are expected to increase by 19 metric tons.

Table 6-13 presents the expected quantities for imports of dry milk into Hong Kong given EU subsidy reductions. Since all of the cross price elasticities and the EU own-price elasticity were not significantly different from zero, results show very little change in the quantities of dry milk imported into Hong Kong. For both percentages of EU subsidy reductions, imports of U.S. dry milk into Hong Kong are expected to decrease by 7 and 13 metric tons for the 36 percent and 72 percent reductions respectively. This is due to the U.S.-EU cross-price elasticity being negative, although not significantly different from zero. Imports from Oceania are expected to increase by 172 metric tons by the year 2003 if reductions are maintained at 36 percent and expected to increase by 302 metric tons if subsidy reductions increased to 72 percent. Since the EU own-price elasticity is positive, although not significantly different from zero, imports are expected to increase by 5 and 9 metric tons if reductions are 36 percent and 72 percent respectively. Dry milk imports from all other sources are expected to decrease by 100 metric tons if reductions are 36 percent and decrease by 178 metric tons if reductions are 73 percent. It is clear that these results are affected by the lack of significance of the elasticities in this system. What is obviously clear is that the quantities of imports from the EU should decrease. However expected imported quantities from the U.S. and Oceania may be to a degree accurate because it is likely that the U.S. will see little increase in imports, while Oceania may be the primary gainer from EU subsidy reductions.

Overall, simulation results suggest that Oceania will be the primary beneficiary from EU subsidy reductions for both rates of reduction. This is in terms of quantity only. In terms of percentage, Hong Kong imports of cheese from the U.S. is expected to increase by 12 percent if policy continues and 21 percent if reductions in subsidies are twice the current rate. Oceania imports will increase by 6 and 10 percent respectively. Forecasts for dry milk imports into Hong Kong indicate Oceania may be the only gainer from subsidy reductions, while imports from all other sources remain unchanged.

Table 6-14 DFAM parameter estimates for Japan imports of cheese

Exporting Country	Price Coefficients, π_{ij}					Marginal Factor Shares, θ_i
	U.S.	Australia	New Zealand	EU	ROW[a]	
U.S.	.-0246 (.0068)[b]***	.0044 (.0202)	.0007 (.0187)	-.0099 (.0117)	.0293 (.0169)*	.0243 (.0061)***
Australia		-.1752 (.1151)	.1162 (.0965)	.1405 (.0640)**	-.0860 (.0757)	.3449 (.0356)***
New Zealand			-.2121 (.1007)**	.0153 (.0470)	.0798 (.0702)	.1766 (.0242)***
EU				-.1950 (.0976)**	.0490 (.0830)	.1937 (.0530)***
ROW					-.0722 (.1145)	.2605 (.0414)***
System R^2 = .81						

[a] ROW= rest of the world.

[b] Asymptotic standard errors are in parentheses.

*** Significant level = .01

** Significant level = .05

* Significant level = .10

Empirical Results for Japan

The following empirical results for the derived demand systems for imports of cheese and whey into Japan are fully constrained (homogeneity and symmetry imposed). Table 6-14 displays the fully constrained parameter estimates for Japan's derived demand for imported cheese. All own-price parameter estimates are negative as to be expected, and the estimates for the U.S., New Zealand, and the EU are significant by at least the .05 significance level. All of the estimates for the marginal factor shares are highly significant for each equation and are all positive indicating that as total imports increase, imports from each source country should also increase

Table 6-15 DFAM parameter estimates for Japan imports of whey

Exporting Country	Price Coefficients, π_{ij}				Marginal Factor Shares, θ_i
	U.S.	Oceania[a]	EU	ROW[b]	
U.S.	-.3662 (.1250)[c]***	.3579 (.0685)***	.1029 (.0735)	-.0947 (.0877)	.3152 (.1707)**
Oceania		-.4953 (.0969)***	.0763 (.0426)*	.0612 (.0830)	.3859 (.0685)***
EU			-.2914 (.0625)***	.1122 (.0645)*	.4372 (.1149)***
ROW				-.0787 (.1274)	-.1384 (.1212)
System R^2 = .80					

[a] Australia and New Zealand aggregation.
[b] ROW= rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significant level = .01
** Significant level = .05
* Significant level = .10

as well. Of all the cross-price coefficients, only two are not significantly different from zero. These are the U.S.-ROW and the Australia-EU coefficients. Both cross-price coefficients indicate that US cheese and cheese from other sources, and Australia and EU cheese are substitutes in Japan. All other cross-price coefficients indicate little to no relationship in other cheese imports (Table 6-14).

Given that the hypothesis of no AR(1) was rejected in the derived demand system for imported whey into Japan, all results have the AR(1) error structure imposed. Table 6-15 displays the parameter estimates for the derived demand for imports of whey into Japan. All own-price coefficients are negative, and with the exception of the ROW, all are significant by at least the .05 significance level. The marginal factor shares estimates indicate a positive relationship between total imports and the imports from the individual sources; however, the marginal factor share estimate for the ROW indicate that as total imports increase, imports from all other sources will decrease. With the exception of the ROW all marginal factor shares are significant by at least the .05 significance level.

Cross-price parameter estimates indicate that the U.S and Oceania whey imports, Oceania and EU imports, and EU and the ROW imports are substitutes. Although not significant, substitution exists between the U.S. and the EU, and Oceania and the ROW as well. The parameter estimate for the U.S. and the ROW indicate a possible complementary relationship; however this estimate is not significant from zero, indicating that imports from these sources may also be independent (Table 6-15).

Table 6-16 displays the elasticities evaluated at the mean for imports of cheese into Japan. The Divisia index elasticities for the U.S. Australia, New Zealand, EU, and the ROW are 0.855, 1.224, 0.727, 0.674, and 1.636 respectively. These elasticities indicate that as that as imports of total cheese into Japan increases, imports from the ROW should increase by the larger percent when compare to the percentage increase in imports from all other sources. Second and third in terms of percentage increase would be Australia and the U.S. respectively. Own-price elasticities for the U.S., Australia, New Zealand, EU and the ROW are -0.867, -0.621, -0.873,-0.678, and-0.453 respectively. All own-price elasticities, with the exception of the ROW are significant. These elasticities indicate inelastic demand for imported cheese in Japan, with the demand for ROW cheese being the most inelastic. The own price elasticities for the U.S. and the EU are more elastic than the elasticities or Australia and New

Table 6-16 Japan Divisia and price elasticities of the derived demand for imported cheese

	Elasticities						
Exporting Country	Divisia Import	Conditional Own-Price	Conditional Cross-Price				
			U.S.	Australia	New Zealand	EU	ROW[a]
U.S.	*.855*[b]	*-.867*		.156	.024	-.347	*1.034*
	(.213)[c]	(.239)		(.711)	(.660)	(.411)	(.594)
Australia	*1.224*	-.621	.016		.412	*.498*	-.305
	(.126)	(.408)	(.071)		(.342)	(.226)	(.268)
New Zealand	*.727*	*-.873*	.003	.478		.063	.329
	(.099)	(.414)	(.077)	(.397)		(.193)	(.288)
EU	*.674*	*-.678*	-.034	*.489*	.053		.170
	(.184)	(.346)	(.040)	(.223)	(.163)		(.289)
ROW	*1.636*	-.453	*.184*	-.540	.501	.308	
	(.422)	(.719)	(.106)	(.476)	(.440)	(.521)	

[a] ROW = rest of the world.

[b] *Italics* indicates that the elasticity was significant by at least .10.

[c] Asymptotic standard errors are in parentheses.

Zealand. This indicates that as prices increase, the percentage decrease in quantities will be smaller for the Oceania countries.

Cross-price elasticities indicate a high degree of substitutability between cheese from the U.S. and the ROW (1.034). The U.S. is also a substitute for the ROW but to a lesser extent (.184). Cross-price elasticities also indicate that Australia and EU cheeses are substitutes as well, both elasticities are about .500 (Table 6-16).

The Divisia index elasticities for imports of whey into Japan are .889, 2.286, 2.352, and -.476 for the U.S., Oceania, EU, and the ROW respectively. These suggest that imports of whey from Oceania and the EU are superior to imports from the U.S. and the ROW. The negative Divisia elasticity for the ROW indicates that whey from

Table 6-17 Japan Divisia and price elasticities of the derived demand for imported whey

	Elasticities					
Exporting Country	Divisia Import	Conditional Own-Price	Conditional Cross-Price			
			U.S.	Oceania[a]	EU	ROW[b]
U.S.	*.889*[c]	*-1.010*		*1.009*	.290	-.267
	(.482)[d]	(.352)		(.193)	(.207)	(.248)
Oceania	*2.286*	*-2.934*	*2.120*		*.452*	.362
	(.559)	(.574)	(.406)		(.253)	(.492)
EU	*2.352*	*-1.568*	.554	*.410*		*.604*
	(.618)	(.338)	(.396)	(.229)		(.347)
ROW	-.476	-.271	-.325	.210	*.386*	
	(.416)	(.438)	(.302)	(.285)	(.222)	

[a] Australia and New Zealand aggregation.

[b] ROW = rest of the world.

[c] *Italics* indicate that the elasticity was significant by at least .10.

[d] Asymptotic standard errors are in parentheses.

all other sources are considered to be inferior inputs in further production processes (Table 6-17).

The own price elasticities are -1.010, -2.934, -1.568, and -.271 for the U.S., Oceania, EU, and the ROW respectively. With the exception of the ROW, these elasticities indicate that Japan's demand for imported whey is elastic; however, the demand for U.S. whey is close to unitary elastic. The own-price elasticity for imports from Oceania indicates that imports from this source have been highly sensitive to price changes (Table 6-17).

Cross-price elasticities of derived demand for whey in Japan indicate significant substitutional relationships between the imports from the exporting sources. The U.S./Oceania cross-price elasticity is 1.009, while the Oceania/U.S.

Table 6-18 Allen-Uzawa partial elasticities of import substitution

Exporting Country	Japan-cheese				
	U.S.	Australia	New Zealand	EU	ROW[a]
U.S.		.554	.100	-1.207	*6.491*[b]
		(2.523)[c]	(2.716)	(1.431)	(3.730)
Australia			1.697	1.733	-1.914
			(1.410)	(.144)	(1.688)
New Zealand				.219	2.063
				(.673)	(1.813)
EU					1.070
					(1.813)
ROW					

[a] ROW = rest of the world.

[b] *Italics* indicates that the elasticity was significant by at least .10.

[c] Asymptotic standard errors are in parentheses.

elasticity is 2.120, again reflecting the higher value placed on Oceania whey that was indicated by the Divisia elasticity. The Oceania/EU and the EU/Oceania elasticities are .452 and .410 respectively, and the EU/ROW and the ROW/EU elasticities are .604 and .386 respectively. All other cross-price elasticities were not different from zero (Table 6-17).

The Allen-Uzawa partial elasticities of import substitution for imported cheese into Japan are all not different from zero, with the exception of the U.S./ROW elasticity. The partial elasticity of substitution for these two goods is 6.491 indicating a strong substitutional relationship between imports of cheese from these two sources (Table 6-18).

Table 6-19 Allen-Uzawa partial elasticities of import substitution

Exporting Country	Japan-whey			
	U.S.	Oceania[a]	EU	ROW[b]
U.S.		*5.981*[c]	1.563	-.918
		(1.145)[d]	(1.116)	(.851)
Oceania			*2.430*	1.245
			(1.359)	(1.691)
EU				*2.075*
				(1.193)
ROW				

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.
[c] *Italics* indicate that the elasticity was significant by at least .10.
[d] Asymptotic standard errors are in parentheses.

The partial elasticities of substitution for imports of whey into Japan indicate a strong substitutional relationship between whey imports from the various source countries. The U.S./Oceania elasticity is 5.981, the Oceania/EU elasticity is 2.430, and the EU/ROW elasticity is 2.075. All other partial elasticities were insignificant (Table 6-19).

Japan's derived demand for imported cheese was re-estimated using all except the last five observations of the data set (1994-1998). Model and elasticity based forecasts were done using the restricted parameters estimates and elasticities. Table 6-20 displays the results of the forecasting procedure where the absolute percentage differences in the actual and forecasts values. The elasticity approach improved forecast by 3 percent on average when compare to model-based forecasts. For the

Table 6-20 Percentage difference in the actual quantities and forecasts for Japan cheese imports: 1994-1998

Year	U.S.	Australia	New Zealand	EU	ROW[a]	Overall Average
Model-Based						
Percent						
1994	16.5	1.3	2.3	2.6	13.6	
1995	34.4	7.5	0.6	11.5	40.9	
1996	56.3	6.6	10.6	4.1	45.0	
1997	61.6	6.5	15.1	13.9	41.8	
1998	66.4	1.8	15.4	8.5	41.6	
Average	47.0	4.7	8.8	8.1	36.6	21.1
Elasticity-Base						
1994	18.8	1.5	2.2	1.9	12.7	
1995	37.5	6.7	1.0	11.8	26.9	
1996	57.8	6.2	11.1	4.3	24.3	
1997	63.3	6.5	15.5	13.6	20.0	
1998	67.9	1.0	16.4	6.8	13.9	
Average	49.1	4.4	9.2	7.7	19.5	18.0

[a] ROW = rest of the world.

remainder of this section, forecasts for the Japan-cheese system are done using elasticities since this approach is the better of the two approaches (Table 6-20).

Recall that the demand system for imported whey has autocorrelated disturbances. The model-based equation (equation (5.5)) can not be used in its present form to make quantity forecasts when the disturbances follow an AR(1) process. The derivation of the forecast model that was used is presented in appendix B.[2]

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[2] The elasticity approach needed no modification.

Table 6-21 Percentage differences in the actual quantities and forecasts for Japan whey imports: 1996-1998

Year	U.S.	Oceania[a]	EU	ROW[b]	Overall Average
		Model-Based (Constrained)			
		Percent			
1996	36.6	75.8	75.3	20.9	
1997	2.3	131.4	42.9	52.5	
1998	16.4	89.2	4.8	39.3	
Average	18.4	98.8	41.0	37.6	48.9
		Elasticity-Based (Constrained)			
1996	22.6	39.5	47.8	28.5	
1997	8.1	44.5	34.7	51.1	
1998	16.7	5.4	7.5	63.3	
Average	15.8	29.8	30.0	47.6	30.8

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

As in the previous case, elasticity-based forecasts provided the more precise forecast estimates when compare to the model-based approach. Forecast precision improved by 18 percent when using the elasticity approach instead of the model-based approach (Table 6-21). For the remainder of this section the elasticity approach is used for all other simulations given that this is the better approach for this system.

Japan cheese import projections are obtained for the period 1999 to 2003 using 1994-98 average annual growth in prices and the 1994-98 Divisia index average. The 1994-98 average annual growth in cheese import prices in Japan for the U.S.,

Table 6-22 Japan cheese imports based on 5-year averages: 1999-2003

Year	U.S.	Australia	New Zealand	EU	ROW[a]
	Metric tons				
1999	4,170.08	81,803.69	54,917.17	36,546.91	16,856.55
2000	4,489.45	90,124.03	56,661.33	36,403.95	18,584.90
2001	4,833.28	99,290.64	58,460.90	36,261.55	20,490.46
2002	5,203.44	109,389.60	60,317.62	36,119.70	22,591.41
2003	5,601.95	120,515.73	62,233.31	35,978.41	24,907.77

[a] ROW = rest of the world.

Australia, New Zealand, EU, and the ROW is –5.2, 1.7, 2.7, 7.8, and 0.9 percent respectively. The 1994-98 Divisia index average is 0.0538.

For the period 1999 to 2003, imports of U.S. cheese into Japan is expected to increase to 5,602 metric tons, an increase of 1,432 metric tons. Imports from Australia are expected to increase to 120,516 metric tons, an increase of 38,516 metric tons. Imports from New Zealand are expected to increase to 62,233 metric tons, an increase of 10,300 metric tons by 2003. Imports from the EU are expected to decrease to 35,879 metric tons, a decrease of 569 metric tons. Imports from all other sources are expected to increase to 16,857 metric tons, an increase of 8,050 metric tons. If trends continue, Australia is expected to have the largest increase in imports of cheese into Japan in terms of quantity; however imports from the ROW is expected to increase by 48 percents while imports from Australia are expected to increase by 47 percent. (Table 6-22).

Table 6-23 Japan whey imports based on 5-year averages: 1999-2003

	U.S.	Oceania[a]	EU	ROW[b]
Year		*Metric tons*		
1999	15,818.00	6,593.51	12,765.74	7,125.13
2000	16,741.99	8,260.37	17,181.23	6,629.33
2001	17,719.96	10,348.62	23,123.99	6,168.03
2002	18,755.05	12,964.79	31,122.28	5,738.84
2003	19,850.61	16,242.34	41,887.06	5,339.51

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

Projections for whey imports into Japan were done for the period 1999 to 2003 based on 5-year averages as well. The 1994-98 average annual growth in prices of imported whey into Japan is 15.5, 12.0, 3.6, and 2.5 percent for the U.S., Oceania, EU, and the ROW respectively. The 1994-98 Divisia index average is 0.1074. These values were used to generate future prices and Divisia index numbers for the period 1999 to 2003.

Forecasts for the period 1999 to 2003 indicate that whey imports from the U.S. will increase from 15,818 to 19,851 metric tons. Imports from Oceania will increase to 16,242 metric tons, an increase of nearly 10,000 metric tons from. EU imports are expected to increase to 41,887 metric tons an increase of 29,000 metric tons. Imports of whey from all other sources are expected to fall by nearly 2,000 metric tons. If trends continue, imports of whey from the EU are expected to increase by a phenomenal 141 percent. This is primarily due to the large Divisia index elasticity, and the strong growth in whey imports into Japan. The increase in imports from the EU is also the result of price increases of 15.5 and 12.0 percent per year in U.S. and Oceania prices respectively. (Table 6-23).

Recall from the previous section that the elasticity of demand price with respect to producer subsidy payments for EU cheese was -0.619. This says that if subsidy reductions are 6 percent per year (36 percent reduction) or 12 percent per year (72 percent reduction), the annual increase in the demand price is 3.7 and 7.4 percent respectively. These values are used to simulate the effects of continuing the UR GATT policy on subsidy reductions or reducing export subsidies by twice the current rate. The EU is the only country that subsidized cheese exports to Japan.

Resulting import quantities from EU subsidy reduction are presented in Table 6-23. Although the parameter estimate and cross-price elasticity for the U.S. and EU was insignificant, it was also negative indicating a complementary relationship between cheese from the EU and the U.S. As a result, 36 and 72 percent subsidy reductions resulted in and decrease in the quantity of cheese imported from the U.S. If subsidy reduction were to continue at the same pace in the upcoming WTO agreement, Japan imports of cheese from the U.S. is expected to fall by 211 metric tons to 3,973 metric ton by the year 2003. If reduction were to double beginning the year 2001, imports would decrease even more to 3,819 metric tons. Given that the U.S./EU cross-price elasticity was insignificant, it is also possible that the subsidy reduction would have no effects on imports from the U.S or lead to increase in imports. The primary beneficiary to a reduction in export subsidies is Australia. For the period 199 to 2003, imports of cheese from Australia are expected to increase to 77,441 metric tons if

Table 6-24 Japan cheese imports given a 36 and 72 percent EU export subsidy reduction: 1999-2003

Year	U.S.	Australia	New Zealand	EU	ROW[a]
			36% Subsidy Reduction:1999-03 *Metric tons*		
1999	4,184.37	71,963.68	53,634.56	37,795.55	16,456.86
2000	4,130.45	73,295.56	53,760.41	36,843.70	16,644.85
2001	4,077.22	74,652.09	53,886.55	35,915.82	16,834.99
2002	4,024.67	76,033.73	54,013.00	35,011.30	17,027.30
2003	3,972.81	77,440.94	54,139.73	34,129.56	17,221.80
			36% Subsidy Reduction:1999-00 72% Subsidy Reduction:2001-03		
1999	4,184.37	71,963.68	53,634.56	37,795.55	16,456.86
2000	4,130.45	73,295.56	53,760.41	36,843.70	16,644.85
2001	4,023.99	76,008.62	54,012.70	34,987.93	17,025.12
2002	3,920.27	78,822.11	54,266.18	33,225.64	17,414.08
2003	3,819.23	81,739.74	54,520.84	31,552.11	17,811.93

[a] ROW = rest of the world.

subsidy reductions in the future are at the same pace, and increase to 81,740 metric tons if the rate in subsidy reductions doubled beginning 2001. In both scenarios imports from Australia are expected to increase by 5,477 and 9,776 metric tons for the 36 percent and 72 percent reduction scenarios respectively and imports quantities in the year 2003 are expected to be 77,441 and 81,740 metric tons respectively. Import from New Zealand are expected to increase but by a smaller amount. For the period 1999 to 2003, cheese imports from New Zealand are expected to increase by 505 and 886 metric tons for the 36 percent and 72 percent reduction scenarios respectively and ending quantities by the year 2003 for both policies are 54,140 and 54,521 metric tons respectively. The own price demand elasticity for the EU is –0.678, which indicates inelastic demand. As a result imports from the EU decreased by 3,666 metric tons for the period 1999 to 2003 when reduction were maintained at 36 percent. If reduction were twice the previous rate, imports would have decreased by 6,224 metric tons. Ending quantities for the EU by the year 2003 for both policy scenarios are 34,130 and 31,552 metric tons respectively. Imports from all other sources are expected to increase by 764 metric tons and 1,355 metric tons if reductions were 36 percent and 72 percent respectively (Table 6-24).

Table 6-25 presents the import quantities of whey imported into Japan if EU subsidy reductions in the future were an extenuation of reductions implemented by the UR GATT or if reductions were twice the rate. For the period 1999 to 2003, imports of whey from the U.S. are expected to increase from 15,757 to 19,475 metric tons if reductions were maintained at 36 percent. If reductions were 72 percent beginning the year 2001, imports would increase to 22,646 metric. For both rates of reduction, U.S. whey imports would increase by 3,800 and 6,900 metric tons respectively. For the same period, Oceania imports of whey are expected to increase from 5,708 to 7,898 metric given a 36 percent reduction and increase to 9,892 metric ton given a 72 percent reduction. Import of whey from the EU are expected to decrease from 6,701 to 1,670 metric tons given a 36 percent reduction, and if subsidy reductions increase to 72 percent import will decrease to 334 metric tons. Imports from all other sources are expected to increase from 8,211 to 10,851 metric tons if reductions are the same and

Table 6-25 Japan whey imports given a 36 and 72 percent EU export subsidy reduction

Year	U.S.	Oceania[a]	EU	ROW[b]
		36% Subsidy Reduction:1999-03 *Metric tons*		
1999	15,757.62	5,708.03	6,701.35	8,210.84
2000	16,614.42	6,190.68	4,734.65	8,803.59
2001	17,517.82	6,714.15	3,345.13	9,439.13
2002	18,470.33	7,281.88	2,363.40	10,120.55
2003	19,474.63	7,897.61	1,669.80	10,851.17
		36% Subsidy Reduction:1999-00 72% Subsidy Reduction:2001-03		
1999	15,757.62	5,708.03	6,701.35	8,210.84
2000	16,614.42	6,190.68	4,734.65	8,803.59
2001	18,421.21	7,237.61	1,955.61	10,074.67
2002	20,424.48	8,461.60	807.75	11,529.28
2003	22,645.60	9,892.58	333.64	13,193.90

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

increase to 13,194 metric tons if reductions doubled starting the year 2001 (Table 6-25).

Imports of whey from the EU are expected to decrease by as much as 95 percent if subsidy reductions were to double the year 2001. This is due to the demand for whey from the EU being elastic in Japan (-1.574). Given maximum reductions in subsidies, Oceania is expected to be the primary beneficiaries in terms of percentage increase in imports (71 percent); however, in terms of quantity, the increase in imports

Table 6-26 DFAM parameter estimates for Mexico imports of butter

Exporting Country	Price Coefficients, π_{ij} U.S.	Oceania[a]	EU	ROW[b]	Marginal Factor Shares, θ_i
U.S.	.0025	-.0325	-.0089	.0389	.1393
	(.0660)[c]	(.0695)	(.0667)	(.0416)	(.0787)**
Oceania		-.3026	.2846	.0505	.4217
		(.1898)	(.1366)**	(.1091)	(.1019)***
EU			-.3078	.0322	.2783
			(.1479)**	(.0846)	(.0915)***
ROW				-.1215	.1607
				(.0976)	(.0583)**
System $R^2 = .83$					

[a] Australia and New Zealand aggregation.

[b] ROW= rest of the world.

[c] Asymptotic standard errors are in parentheses.

*** Significant level = .01

** Significant level = .05

* Significant level = .10

from the U.S. is expected to increase by 6,900 metric tons, which is the largest increase of all exporting sources.

Empirical Results for Mexico

Due to missing observations, Mexico's demand for imported butter was estimated for the period 1971 to 1998. Results of the estimation procedure are presented in Table 6-21. Of all the own-price coefficients, all have negative signs except the own price coefficient for the U.S; however, the EU own price coefficient is the only one that is significantly different from zero. Parameter estimates for the marginal factor share are all positive and are significant for each exporting source,

Table 6-27 Mexico Divisa and price elasticities of the derived demand for imported butter

		Elasticities				
Exporting Country	Divisa Import	Conditional Own-Price	Conditional Cross-Price			
			U.S.	Oceania	EU	ROW[a]
U.S.	*.809*[b]	.015		-.188	-.052	.226
	(.457)[c]	(.383)		(.403)	(.387)	(.241)
Oceania	*1.203*	-.863	-.093		*.812*	.144
	(.291)	(.541)	(.055)		(.389)	(.311)
EU	*.696*	*-.770*	-.022	*.712*		.080
	(.229)	(.370)	(.167)	(.342)		(.212)
ROW	*2.078*	-1.571	.503	.652	.416	
	(.754)	(1.263)	(.537)	(1.410)	(1.094)	

[a] ROW = rest of the world.

[b] *Italics* indicates that the elasticity was significant by at least .10.

[c] Asymptotic standard errors are in parentheses.

indicating that as total imports of butter increase in Mexico, imports from each individual source increase as well. All cross-price coefficients are not significantly different from zero except for the Oceania/EU cross-price which significant at the .05 significance level. This coefficient is also positive indicating that butter imports from these sources are substitutes in Mexico.

Table 6-27 presents the Divisia and price elasticities of Mexico's derived demand for imported butter. The Divisia elasticities for the U.S., Oceania, EU, and the ROW are 0.809, 1.203, 0.696, and 2.078 respectively. This indicates that as total imports of butter increase into Mexico, the largest percentage increase will be in imports from all other sources, where for every weighted percentage increase in total imports of butter, butter imports from the ROW will increase by 2.078 percent.

The own-price elasticities for the U.S., Oceania, EU, and the ROW are 0.015, -0.868. –0.770, and –1.571 respectively. Of these price elasticities, the EU own-price is the only own-price elasticity that is significant by at least the .10 significance level. The incorrect sign and insignificance of the U.S. own-price elasticity may be due the U.S. being the closest major dairy exporter to the Mexican dairy market. This is to say that since U.S. butter is more accessible that butter from other sources, then imports from the U.S. may depend only on the total imports and not necessarily on the price of the commodity. All cross-price elasticities are insignificant except for the Oceania/EU and the EU/Oceania elasticities. These elasticities are 0.812 and 0.712 for the Oceania/EU and the EU/Oceania respectively. Both cross-price elasticities indicate also indicate that butter from theses sources are substitutes. Given that imports of butter from Oceania is significantly a substitutes for EU butter in Mexico and given that all other cross-price relationships are insignificant, Oceania is potentially the primary gainer from EU subsidy reductions. Although insignificant, the cross-price elasticities of the demand for U.S. butter with respect to changes in the competing country prices, elasticities indicate a complementary relationship between U.S butter and butter from Oceania and the EU. This suggest that as export subsidies decrease for the EU, imports from the U.S. will decrease as well; however, given that this elasticity is not different from zero, there is also the possibility of an increase in U.S. or no change at all (Table 6-27).

There is very little that can be said about the Allen-Uzawa partial elasticities of substitution. Of all the elasticities only one is significant; that is the Oceania/EU partial elasticity which is 2.030 (Table 6-28). This indicates that butter imports from

Table 6-28 Allen-Uzawa partial elasticities of import substitution

Exporting Country	Mexico-butter			
	U.S.	Oceania[a]	EU	ROW[b]
U.S.		-.537	-.130	2.918
		(1.150)[d]	(.969)	(3.119)
Oceania			*2.030*[c]	1.861
			(.974)	(4.023)
EU				1.040
				(2.735)
ROW				

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.
[c] *Italics* indicate that the elasticity was significant by at least .10.
[d] Asymptotic standard errors are in parentheses.

these sources are considered to be substitutes by produces of products that used the butter imports as inputs.

Mexico's derived demand for imported butter was re-estimated using all of the observations except for the last three years (1996-98). Using both the model-based and elasticity based forecasting equations, forecasts were made for the remaining years and then compared to the actual quantities imported. Table 6-29 presents the absolute percentage difference in the forecasts and actual quantities for the period 1996 to 1998. Results indicate that using the elasticity approach over the model improved forecasts on average by 40 percent.

For both approaches, forecasts are off by as much as 280 percent and for the U.S., and forecasts were off by 182 and 222 percent on average for the model and elasticity approach respectively. The reason for this occurrence is that the U.S. share

Table 6-29 Percentage differences in the actual quantities and forecasts for Mexico butter imports: 1996-1998

Model-Based

Year	U.S.	Oceania[a]	EU	ROW[b]	Overall Average
		Percent			
1996	82.9	66.6	12.8	351.7	
1997	190.0	54.4	11.4	349.9	
1998	273.5	43.6	13.8	137.8	
Average	182.1	54.9	12.7	279.8	132.4
		Elasticity-Based			
1996	108.2	48.0	16.8	75.3	
1997	237.0	57.7	19.3	69.5	
1998	319.4	50.0	18.4	84.9	
Average	221.5	51.9	18.2	76.6	92.0

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

of total imports in Mexico has been on average less than 10 percent. Therefore forecasts may be off by about the same quantity for each country, but given the U.S. small market share, this results in a higher percentage difference. Also note that the DFAM is a first difference model, therefore the resulting model-base equation is not only dependent the exogenous variables, but also dependent on quantities for the previous year. The elasticity approach uses last year quantities as well. When there are large changes in imports from year to year, both models had problems in forecasting. For example, U.S. butter imports into Mexico was over 8,000 metric tons in 1995 and dropped to 5,000 metric ton in 1996 and then to 3000 in 1997. In 1998, imports again fell to 2,400 metric tons. Both approaches started with the quantity 8,000 metric tons and forecasts were made given this quantity. Given the model insignificant estimates and elasticities, forecasts stayed in the 8,000 metric ton range for the forecasting period, which made forecasts in 1998 off by about 300 percent for both models.

Of the two approaches, elasticity-based forecasts were on average closer to the actual quantities (Table 6-29). Therefore elasticity-based simulations will be used for the remainder of this section. Simulation of butter imports into Mexico for the period 1999 to 2003 were obtained using the 1994-98 average annual growth in prices and the 1994-98 Divisia index average. The 1994-98 average annual growth in U.S., Oceania, EU and ROW prices is 3.8, 2.8, 9.9 and 8.7 percent respectively. The 1994-98 Divisia index average is -0.08445. This reflects the fact that imports of butter have been decreasing the last 5 years. Expected butter imports into Mexico based on 5-year trends are presented in Table 6-30. For the period 1999 to 2003 imports of butter from the U.S are expected to decrease from 2,297 metric tons to 1,805 metric tons, a decrease of 492 metric tons by the end of the period. Imports from Oceania are expected to decrease from 16,678 metric tons to 14,397 metric tons, and imports from the EU are expected to decrease from 4,799 metric tons to 3,022 metric tons for the same period. Imports from all other sources (ROW) are expected to decrease from 1,691 metric tons to 584 metric tons by the end of the period (Table 6-30). If trends continue, the source country that will be the least affected by the continual decline in import and increasing prices is Oceania where imports of butter into Mexico will decrease by 13.7 percent. Imports of butter from the U.S. are expected to decrease by 21 percent. If trends continue, imports from the EU and the ROW will be the hardest

Table 6-30 Mexico butter imports based on 5-year averages: 1999-2003

Year	U.S.	Oceania[a]	EU	ROW[b]
	Metric tons			
1999	2,297.20	16,677.50	4,799.47	1,691.33
2000	2,162.76	16,075.54	4,275.23	1,296.73
2001	2,036.19	15,495.30	3,808.25	994.19
2002	1,917.03	14,936.01	3,392.27	762.24
2003	1,804.84	14,396.91	3,021.74	584.41

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

hit percentage wise where imports are expected to decrease by 37 and 65 percent for the EU and the ROW respectively.

Since the U.S. and the EU subsidized exports to Mexico, the reduction in export subsidies by both countries is considered. As before, the two subsidy reduction commitments investigated are the continuation of current subsidy policy (36 percent reduction) or a more aggressive reduction commitment (72 percent). According to the United States Department of Agriculture the elasticity of supply for the U.S. and the EU is 0.50 and 0.65 respectively, and the demand elasticity for butter is -0.46 and -0.43 respectively. Using equation (5.7) the elasticity of demand price with respect to a subsidy payment change is -0.521 and -0.602 for the U.S. and the EU respectively. Assuming the future WTO agreement period is the same as the UR GATT implementation period (6 years), the 36 and 72 percent implies an average annual reduction of 6 and 12 percent respectively. As before, the 72 percent reduction is applied to the period 2001 to 2003 since the UR GATT period ends the year 2000.

Table 6-31 shows the imported quantities for the period 1999 to 2003 given a 36 and 72 percent subsidy reduction by the U.S. and the EU. If future policy is a continuation of the UR GATT then imports of butter from the U.S. into Mexico is expected to decrease from 2,419 metric ton to 2,338 metric tons by the year 2003. For the same period, imports from Oceania are expected to increase from 20,045 to 36,113 metric tons, and the EU is expected to decrease from 4,466 to 2,108 metric tons. Imports from all other sources are expected to increase from 2,613 to 5141 metric tons by the year 2003. If the new WTO agreement pursues the reduction of export subsidies more aggressively such that it is twice the average annual rate of reduction implemented by the UR GATT agreement then butter imports from the U.S. will decrease even further to 2,259 metric tons by the year 2003. Imports from Oceania will increase to 60,321 metric ton, and the EU will decrease even further to 837 metric tons. Imports from the ROW will increase to 9,171 metric tons by the year 2003 (Table 6-31).

The primary gainer from export subsidy reductions in this case is Oceania. Assuming a 72 percent reduction commitment by the U.S. and the EU, imports of butter from Oceania are expected to increase by 201 percent and imports from the ROW are expected to increase by 251 percent. Given the close proximity of the U.S. and given that it maintains a small share of total subsidy expenditures allowed under the WTO, the fall in imports from the U.S. is significantly less than the fall in imports from the EU. If subsidies are reduced by 72 percent, imports from the EU are expected

Table 6-31 Mexico butter imports given a 36 and 72 percent EU export subsidy reduction

Year	U.S.	Oceania[a]	EU	ROW[b]
		36% Subsidy Reduction:1999-03		
		Metric tons		
1999	2,419.23	20,045.14	4,466.37	2,612.76
2000	2,398.63	23,223.20	3,702.39	3,094.52
2001	2,378.21	26,905.12	3,069.09	3,665.11
2002	2,357.96	31,170.79	2,544.11	4,340.90
2003	2,337.89	36,112.76	2,108.94	5,141.31
		36% Subsidy Reduction:1999-00 72% Subsidy Reduction:2001-03		
1999	2,419.23	20,045.14	4,466.37	2,612.76
2000	2,378.03	26,401.26	2,938.41	3,576.28
2001	2,337.54	34,772.82	1,933.17	4,895.11
2002	2,297.74	45,798.93	1,271.82	6,700.30
2003	2,258.62	60,321.30	836.73	9,171.20

[a] Australia and New Zealand aggregation.
[b] ROW = rest of the world.

to fall by 81 percent while imports from the U.S. are expected to fall by only 6.7 percent.

In summary, the DFAM estimation procedure fit well for 3 of the 5 systems. These systems were Hong Kong-cheese, Japan cheese, and Japan whey. In each of these systems the own price parameters were all the correct sign and significant. The marginal factor share, which is the Divisa index coefficient, was significant in each system for each equation except for the ROW in some cases. This indicates that imports from the various source countries are significantly dependent upon the total import decision, which says that as total imports increase, imports from the each of the source countries will increase as well.

Own and cross-price elasticities indicate that imports of U.S. cheese into Hong Kong is highly elastic while imports from all other sources are unitary elastic or inelastic. Also U.S. cheese is highly substitutable for EU cheese in Hong Kong, more so than cheese from any other source. Own-price elasticities in for imported cheese into Japan indicate that imported cheese is inelastic to unitary elastic for cheese from all sources. Cross-price elasticities indicate that in Japan Australia cheese is the only cheese that is a significant substitute for EU cheese. The highest degree of substitution in the Japan whey market is between U.S. and Oceania whey. Cross-price elasticities indicate that imports of U.S. whey should increase by 1 percent for every percentage increase in the price of Oceania whey; however, for every percentage increase in the U.S. price, imports from Oceania should increase by 2 percent.

Of the two forecast approaches, elasticity-based forecasts for each system were better predictors than model-based forecasts. In a comparison of the percentage difference between the actual values and the forecasts from the two approaches, use of the elasticity approach improved forecasts by as much as 18 percent on average for each of the systems. Results also indicate that use of theoretical constraints improved forecasts even when constraints were rejected.

Forecasts based on 1994-98 averages and forecasts given the reduction in export subsidies indicate that Australia and New Zealand (Oceania) will be the primary gainers in terms of the quantity dairy products imported. However, the percentage increase in imports for products from the U.S., EU, and the ROW was greater in some instances and for imports of whey into Japan, the EU was expected to be the primary gainer in terms of both quantity and percent.

Of all the forecasts given EU subsidy reductions and EU and U.S. subsidy reductions for Mexico, imports of whey into Japan and cheese into Hong Kong are the only instances where imports from the U.S. showed significant increases. Given aggressive reductions in subsidies (72 percent), imports of whey into Japan was expected to increase by 43 percent and imports of cheese into Hong Kong was expected to increase by 19 percent which was the largest percentage increase of all the countries. U.S. imports for the other systems showed little or a negative change given EU subsidy reductions. In the case of Mexico's imports of butter, U.S. subsidy reductions resulted in a smaller percentage decrease in imports when compared to the import decrease for the EU.

CHAPTER 7
SUMMARY AND CONCLUSIONS

This study is an attempt to assess the competitiveness of U.S. dairy products in selected international markets considered to be potential major importers of dairy products and particularly U.S. dairy products. Given the total elimination of dairy price supports by January 1, 2000, and given the 21 percent quantity and 36 percent expenditure reduction in subsidized dairy exports, U.S. producers of dairy products have gained interest in obtaining a greater market share of international markets. Given that the U.S. has had a relatively small market share of world dairy trade, the degree to which U.S. products compete in international markets is unknown. This study attempts to give the U.S. dairy industry a snapshot of how products have been competing on average from past to present. The competitiveness of U.S. dairy products was assessed by estimating the responsiveness of quantities imported from the U.S. to factors such as total imports, U.S. prices, and prices of the same product produced by other exporting countries.

A primary objective of this study was to develop the differential approach to the theory of the firm and to present the methodology of how it can be applied to the derived demand for imported dairy products. Although the application of production theory to international trade is by no means a new concept, this study is the first to utilize production theory as a means of estimating the import demand for an individual product, particularly a product differentiated by the source country of origin. Past studies that have attempted this type of analysis utilized consumer theory as a means of obtaining estimates and elasticities. In these studies, imports are considered to be final goods that enter directly into the consumer's utility function and the resulting demand equations for imports are derived from consumer maximization theory. However, given the nature of international trade, where traded goods are either used in other production processes or they may go through a number of domestic channels before reaching the consumer, it is more appropriate to view imported goods as intermediate products than as final consumption goods even if no transformation takes place. Therefore the production approach to import demand analysis developed in this study is an improvement on the current methodology that is widely used to assess import demand. This is because this approach more accurately assesses the way in which goods are imported.

Additional objectives of this study were to project future derived demand for dairy products in the selected international markets, and to simulate the effects of trade liberalization. Given the left-hand side of the differential factor allocation model (DFAM), quantity forecasts are not easily obtained. In this study two methods were developed as a means of obtaining quantity forecasts. The first approach was a model-based approach, which used the estimated model as a mean of forecasting future quantities. Given the difficulty in forecasting with differential models due to the complex dependent variable, past studies have not investigated the forecasting power of these type models. One attempt was a study by Kastens and Brester (1996), which utilized a Taylor series expansion on the left-hand side of the differential consumer model to simplify it such that quantity forecasts could be made. Although the DFAM and the differential consumer model (Rotterdam model) are highly similar structurally, model-based forecasts in this study were accomplished by using the models itself and not a Taylor series approximation. The complexity of the resulting forecasting equation required the Gauss-Seidel algorithm to solve for the individual quantities. The second method was an elasticity-based approached derived from elasticity equations. This method simply used the actual or projected percentage changes in the exogenous variable and used elasticities to make forecasts on the quantities imported. Of the two approaches, this study found that forecasts using elasticities were more precise in predictions when compared to model based forecasts.

The competitiveness of U.S. dairy products was assess by estimating the percentage responsiveness of quantities imported to factors such as total imports, own price and the price of cross-country substitutes in selected international markets. The target international markets that were studied were the Hong Kong, Japan, and Mexico. These countries were selected because they offer the greatest potential for increased imports of dairy products due to trade liberalization and Western influence. Results of this study indicate that in Hong Kong, quantities of cheese and dry milk imported from the U.S. had relatively larger Divisia import index elasticities when compare to other exporting sources. This indicates that imports from the U.S. should increase as Hong Kong's total imports of cheese and dry milk increase by a greater percent when compare to other exporting sources. However, own price elasticities indicate that Hong Kong's derived demand for U.S. cheese is highly elastic which says that U.S. imports are more sensitive to price changes that imports from all other sources. In Japan the Divisia import index elasticity for cheese and whey imported from the U.S. was not of the higher Divisia elasticities when compared to the other exporting countries. This suggests that although imports from the U.S. may increase with increases in Japan's total imports, imports from source countries other than the U.S. should increase by a greater percent. Price elasticities indicate that the derived demand for U.S. cheese and whey in Japan is inelastic and unitary elastic respectively. Cross-price elasticities in Hong Kong and Japan indicate a substitution relationship between the import from the various sources, except for the Hong Kong dry milk markets where mostly all of the cross-price elasticities were not different from zero. In the Hong Kong cheese market, cross-price elasticities indicate that imports from the U.S. are used to greater extent when substituting for EU imports than imports from Oceania. This indicates that the U.S. should gain percentage wise in the Hong Kong cheese market as EU subsidy reductions cause EU prices to rise. The Divisia elasticities for Mexico's derived demand for butter is similar to the elasticities for Japan. These elasticities indicate that imports from the U.S. will increase by a lesser percent when compared to other exporters when the total imports of butter increase. Similar to the Hong Kong dry milk results, little to no relationship was identified in the price elasticities.

Forecast based on 1994-98 averages and forecasts given the reduction in export subsidies indicate that Australia and New Zealand (Oceania) will be the primary gainers in terms of the quantity dairy products imported. However, the percentage increase in imports for products from the U.S., EU, and the ROW was greater in some instances and for imports of whey into Japan, the EU was expected to be the primary gainer in terms of both quantity and percent. Of all the forecasts given EU subsidy reductions and EU and U.S. subsidy reductions for Mexico, imports of whey into

Japan and cheese into Hong Kong are the only instances where imports from the U.S. showed significant increases. Given aggressive reductions in subsidies (72 percent), imports of whey into Japan was expected to increase by 43 percent and imports of cheese into Hong Kong was expected to increase by 19 percent which was the largest percentage increase of all the countries. U.S. imports for the other systems showed little or a negative change given EU subsidy reductions. In the case of Mexico's imports of butter, U.S. subsidy reductions resulted in a smaller percentage decrease in imports when compared to the decrease for the EU.

Estimation and simulation results send a clear message to the U.S. dairy industry. Given the parameter estimates, simulation results indicate that Mexico butter imports from the U.S. will likely decrease as subsidy reductions continue. Therefore if the U.S. is to maintain or increase market share, efforts to promote U.S. butter in Mexico must be expanded. For those products where imports from the U.S. were expected to increase (Hong Kong-cheese and Japan-whey) due to further export subsidy reductions by the EU, efforts to promote these products can further increase market share. The Japanese market is one of the world largest markets for imported cheese, however, estimation and simulation results suggest that the U.S. will see little benefit from EU subsidy reductions. If the U.S. is going to gain greater access to this market, promotional efforts must be made such that Japanese firms see U.S. cheese as a viable alternative to EU cheese. The same is also true for the Hong Kong dry milk market.

Dobson (1997) noted that the U.S. advantage in international markets would be in dairy products that are high differentiable by brand name and quality. Highly differentiable products include products such as ice creams, cheeses, yogurts, and other dairy products that can be differentiated by brand name. Dobson's rationale was that these products would typically receive a premium if perceived to be better quality than other generic brands. This suggests that the DFAM application should be extended to products where a high degree of differentiation occurs within the markets. This was partly accomplished in this study where the derived demand for cheese in Hong Kong and Japan was assessed. Results of this study showed that differentiating products by source country of production was more applicable to the cheese systems than for the butter and dry milk system. This suggests that further research should deal primarily with products that are highly differentiable. However, the estimation for the derived demand for whey into Japan was a good fit and had a number of significant price parameters even though this product is primarily used as an ingredient in cattle feed and infant formulas. This also suggests that the assumption that differences due to the source country of production may apply to some physically indistinguishable products as well depending on the importing market chosen. Therefore analysis should not just be limited to highly differentiable products.

Lastly, Japan and Mexico have implemented trade policy that should likely increase total imports of dairy products. These policies include the tariffication of all non-competitive barriers to imports such as import levies and quotas, the reduction of tariff rates, and the reduction in domestic support. Given that each of these policies should increase total imports, further research should investigate the effects of these policies on imports from the various exporting sources. To some degree this was done in this study when forecasts were made using the 5-year average Divisia index.

APPENDIX A
THE FUNDAMENTAL MATRIX EQUATION OF THE FIRM

The matrix equation of the firm is comparable to the Barten's fundamental matrix equation of the consumer (Barten, 1964). Recall the cost minimization problem

$$\underset{x}{Min} \quad w'x \qquad s.t. \qquad h(q,x)=0 \tag{A.1}$$

where the Langrangian function for this problem is

$$L(x,\lambda)=\sum_{i=1}^{n} w_i x_i - \lambda h(q,x) \tag{A.2}$$

and the first order conditions are

$$\frac{\partial L(x,\lambda)}{\partial \log x_i} = w_i x_i - \lambda \frac{\partial h(q,x)}{\partial \log x_i} = 0 \tag{A.3a}$$

$$\frac{\partial L(x,\lambda)}{\partial \lambda} = h(q,x) = 0\,. \tag{A.3b}$$

Differentiating the first order conditions with respect to log q_r and log w_i yield

$$\begin{aligned} & w_i x_i \frac{\partial \log x_i}{\partial \log q_r} - \lambda \frac{\partial h}{\partial \log x_i}\frac{\partial \log \lambda}{\partial \log q_r} - \lambda \sum_{j=1}^{n} \frac{\partial^2 h}{\partial \log x_i \partial \log x_j}\frac{\partial \log x_j}{\partial \log q_r} \\ & - \lambda \frac{\partial^2 h}{\partial \log x_i \partial \log q_r} = 0 \end{aligned} \tag{A.4}$$

$$\sum_{i=1}^{n} \frac{\partial h}{\partial \log x_i}\frac{\partial \log x_i}{\partial \log q_r} + \frac{\partial h}{\partial \log q_r} = 0 \tag{A.5}$$

$$\delta_{ij} w_i x_i + w_i x_i \frac{\partial \log x_i}{\partial \log w_j} - \lambda \frac{\partial h}{\partial \log x_i} \frac{\partial \log \lambda}{\partial \log w_j} \\ - \lambda \sum_{k=1}^{n} \frac{\partial^2 h}{\partial \log x_i \partial \log x_k} \frac{\partial \log x_k}{\partial \log w_j} = 0 \tag{A.6}$$

$$\sum_{i=1}^{n} \frac{\partial h}{\partial \log x_i} \frac{\partial \log x_i}{\partial \log w_i} = 0. \tag{A.7}$$

In equation (A.6), δ_{ij} is the Kronecker delta that is equal to 1 if $i = j$, and 0 otherwise.

Writing the total cost as $C = \boldsymbol{w}'\boldsymbol{x}$, the *ith* factor share of total cost is defined as $f_i = w_i x_i / C$. Additionally, let $\boldsymbol{F}$ (n×n) be a diagonal matrix where each factor share is along the diagonal and let the logarithmic second-order derivatives of the production function *h*( ) be

$$\boldsymbol{H} = \frac{\partial^2 h}{\partial(\log \boldsymbol{x})\partial(\log \boldsymbol{x}')} \quad (n \times n), \tag{A.8a}$$

$$\boldsymbol{H}^* = \frac{\partial^2 h}{\partial(\log \boldsymbol{x})\partial(\log \boldsymbol{q}')} \quad (n \times m), \tag{A.8b}$$

$$\boldsymbol{H}^{**} = \frac{\partial^2 h}{\partial(\log \boldsymbol{q})\partial(\log \boldsymbol{q}')} \quad (m \times m), \tag{A.8c}$$

Using the matrix ***F***, *H*, *H**, and the first order condition, equation (A.3a), and dividing equations (A.4) and (A.6) by *C*, equations (A.4) through (A.7) can be simplified and express in matrix notation as

$$(\boldsymbol{F}-\gamma\boldsymbol{H})\frac{\partial\log\boldsymbol{x}}{\partial\log\boldsymbol{q}'}-\boldsymbol{F}\iota\,\frac{\partial\log\lambda}{\partial\log\boldsymbol{q}'}=\gamma\boldsymbol{H}* \tag{A.9}$$

$$\iota\,'\boldsymbol{F}\frac{\partial\log\boldsymbol{x}}{\partial\log\boldsymbol{q}'}=\gamma\boldsymbol{g}' \tag{A.10}$$

$$(\boldsymbol{F}-\gamma\boldsymbol{H})\frac{\partial\log\boldsymbol{x}}{\partial\log\boldsymbol{w}'}-\boldsymbol{F}\iota\,\frac{\partial\log\lambda}{\partial\log\boldsymbol{w}'}=-\boldsymbol{F} \tag{A.11}$$

$$\iota\,'\boldsymbol{F}\frac{\partial\log\boldsymbol{x}}{\partial\log\boldsymbol{w}'}=\mathbf{0} \tag{A.12}$$

Note that $\gamma = \lambda/C$ (Chapter 3) and $\boldsymbol{g}$ is a m element column vector whose *rth* element is defined by the product share equation (3.9). If we Premultiplying equation (A.9) and (A.11) by $\boldsymbol{F}^{-1}$, Equations (A.9) through (A.12) are expressed as a partitioned matrix equation

$$\begin{bmatrix}\boldsymbol{F}^{-1}(\boldsymbol{F}-\gamma\boldsymbol{H})\boldsymbol{F}^{-1} & \iota \\ \iota\,' & \mathbf{0}\end{bmatrix}\begin{bmatrix}\boldsymbol{F}\dfrac{\partial\log\boldsymbol{x}}{\partial\log\boldsymbol{q}'} & \boldsymbol{F}\dfrac{\partial\log\boldsymbol{x}}{\partial\log\boldsymbol{w}'} \\ -\dfrac{\partial\log\lambda}{\partial\log\boldsymbol{q}'} & -\dfrac{\partial\log\lambda}{\partial\log\boldsymbol{w}'}\end{bmatrix}. = \begin{bmatrix}\gamma\boldsymbol{F}^{-1}\boldsymbol{H}* & -\boldsymbol{I} \\ \gamma\boldsymbol{g}' & \mathbf{0}\end{bmatrix} \tag{A.13}$$

where the partitioned matrix of derivatives can be solved for by using

$$\begin{bmatrix} \boldsymbol{F}\dfrac{\partial \log \boldsymbol{x}}{\partial \log \boldsymbol{q}'} & \boldsymbol{F}\dfrac{\partial \log \boldsymbol{x}}{\partial \log \boldsymbol{w}'} \\ -\dfrac{\partial \log \lambda}{\partial \log \boldsymbol{q}'} & -\dfrac{\partial \log \lambda}{\partial \log \boldsymbol{w}'} \end{bmatrix} = \begin{bmatrix} \boldsymbol{F}^{-1}(\boldsymbol{F}-\gamma\boldsymbol{H})\boldsymbol{F}^{-1} & \iota \\ \iota' & \mathbf{0} \end{bmatrix}^{-1} \begin{bmatrix} \gamma\boldsymbol{F}^{-1}\boldsymbol{H}^{*} & -\boldsymbol{I} \\ \gamma\boldsymbol{g}' & \mathbf{0} \end{bmatrix} \tag{A.14}$$

Using the rule for an inverse of a partitioned matrix[1], it is verified that

$$\begin{bmatrix} \boldsymbol{F}^{-1}(\boldsymbol{F}-\gamma\boldsymbol{H})\boldsymbol{F}^{-1} & \iota \\ \iota' & \mathbf{0} \end{bmatrix}^{-1} = \begin{bmatrix} \Psi(\boldsymbol{\Theta}-\boldsymbol{\theta}\boldsymbol{\theta}'') & \boldsymbol{\theta} \\ \boldsymbol{\theta}' & -1/\Psi \end{bmatrix} \tag{A.15}$$

where

$$\Psi = \boldsymbol{\iota}'\boldsymbol{F}(\boldsymbol{F}-\gamma\boldsymbol{H})^{-1}\boldsymbol{F}\boldsymbol{\iota}\ , \tag{A.16}$$

$$\boldsymbol{\Theta} = \frac{1}{\Psi}\boldsymbol{F}(\boldsymbol{F}-\gamma\boldsymbol{H})^{-1}\boldsymbol{F}\,, \tag{A.17}$$

$$\boldsymbol{\theta} = \boldsymbol{\Theta}\iota = \frac{1}{\Psi}\boldsymbol{F}(\boldsymbol{F}-\gamma\boldsymbol{H})^{-1}\boldsymbol{F}\boldsymbol{\iota}\ . \tag{A.18}$$

Using the inverse matrix (A.15) yield the following solutions for (A.14):

$$\frac{\partial \log \lambda}{\partial \log \boldsymbol{w}'} = \boldsymbol{\theta}'\ , \tag{A.19}$$

$$\boldsymbol{F}\frac{\partial \log \boldsymbol{x}}{\partial \log \boldsymbol{w}'} = -\ \Psi(\boldsymbol{\Theta}-\boldsymbol{\theta}\boldsymbol{\theta}'\ )\,, \tag{A.20}$$

---

[1] The inverse of a partitioned matrix, $A = \begin{bmatrix} B & C \\ D & E \end{bmatrix}$, equals

$A^{-1} = \begin{bmatrix} B^{-1} + B^{-1}CF^{-1}DB^{-1} & -B^{-1}CF^{-1} \\ -F^{-1}DB^{-1} & F^{-1} \end{bmatrix}$, where $F = \mathrm{E} - \mathrm{D}\mathrm{B}^{-1}\mathrm{C}$.

$$\frac{\partial \log \lambda}{\partial \log \boldsymbol{q}'} = \frac{\gamma}{\Psi}\boldsymbol{g}' - \gamma\theta' \boldsymbol{F}^{-1}\boldsymbol{H}^{*}, \tag{A.21}$$

$$\boldsymbol{F}\frac{\partial \log \boldsymbol{x}}{\partial \log \boldsymbol{q}'} = \gamma\boldsymbol{\theta}\boldsymbol{g}' - \gamma\,\Psi(\boldsymbol{\Theta} - \boldsymbol{\theta}\boldsymbol{\theta}')\boldsymbol{F}^{-1}\boldsymbol{H}^{*} = \gamma\boldsymbol{K}\boldsymbol{G} \tag{A.22}$$

K is an n×m matrix which has θ_i^r as its *(i,r)th* element and ***G*** is a diagonal matrix where the product shares (3.9) are along the diagonal.

APPENDIX B
FORECASTING WITH THE DFAM IN THE PRESENCE OF AR(1) DISTURBANCES

Forecasting with the DFAM is not accomplished in the manner in which most models are used for forecast. Given that the left-hand side of the DFAM is a nonlinear transformation of the quantity demanded, forecasting requires special treatment. In chapter 5 the resulting model -base forecasting equation was

$$x_{it} = \exp\left[\frac{\theta_i DX_t + \sum_{j=1}^{n} \pi_{ij} (\log w_{it} - \log w_{it-1})}{\dfrac{\dfrac{w_{it} x_{it}}{\sum_{i=1}^{n} w_{it} x_{it}} + \dfrac{w_{it-1} x_{it-1}}{\sum_{i=1}^{n} w_{it-1} x_{it-1}}}{2}} + \log x_{it-1} \right]. \tag{B.1}$$

However, when disturbances are autocorrelated and are corrected for in the estimation, equation (B.1) must further be modified.

Green (1997) indicates that for the AR(1) transform model, $y_t^* = x_t^{*'}\beta + \varepsilon_t^*$, forecasts about y in period t+1 are accomplished by first disassembling the model. Forecast in period t+1for the AR(1) corrected model is $\hat{y}_{t+1}^0 = x_{t+1}^{*'}\hat{\beta}$. This implies that

$$\begin{aligned} \hat{y}_{t+1}^0 - \rho y_t &= x_{t+1}^{*'}\hat{\beta} - \rho x_t^{*'}\hat{\beta} \\ \hat{y}_{t+1}^0 &= x_{t+1}^{*'}\hat{\beta} + \rho (y_t - x_t^{*'}\hat{\beta}) \\ \hat{y}_{t+1}^0 &= x_{t+1}^{*'}\hat{\beta} + \rho e_t \end{aligned} \tag{B.2}$$

Applying this procedure to the DFAM results in

$$\bar{f}_{it+1}\hat{D}\,x_{it+1} = \hat{\theta}_i D\,X_{t+1} + \sum_{j=1}^{n}\hat{\pi}_{ij}\ D\,w_{jt+1} + \rho e_{it} \tag{B.3}$$

where $e_{it} = \bar{f}_{it}\hat{D}\,x_{it} - (\hat{\theta}_i D\,X_t + \sum_{j=1}^{n}\hat{\pi}_{ij}\ D\,w_{jt})$. Using equation (B.3), the model-based forecasting equation with AR(1) is

$$x_{it+1} = \exp\left[\frac{\begin{array}{l}\theta_i DX_{t+1} + \sum_{j=1}^{n}\pi_{ij}Dw_{it+1} - \rho\,\dfrac{\dfrac{w_{it}x_{it}}{\sum_{i=1}^{n}w_{it}x_{it}} + \dfrac{w_{it-1}x_{it-1}}{\sum_{i=1}^{n}w_{it-1}x_{it-1}}}{2}(\log x_t - \log x_{t-1}) \\ + \rho(\theta_i DX_t + \sum_{j=1}^{n}\pi_{ij}Dw_{it})\end{array}}{\dfrac{\dfrac{w_{it+1}x_{it+1}}{\sum_{i=1}^{n}w_{it+1}x_{it+1}} + \dfrac{w_{it}x_{it}}{\sum_{i=1}^{n}w_{it}x_{it}}}{2}} + \log x_t\right]. \tag{B.4}$$

Equation (B.4) was used for model-based forecast of whey imports into Japan.

REFERENCES

American Consulate General. *Annual Marketing Plan-Hong Kong*. Report 62, Washington D.C., 1996.

Armington, P.S. "A Theory of Demand for Products Distinguished by Place of Production." *International Monetary Fund Staff Papers* 16(1969): 159-76.

Barten, A.P. "Maximum Likelihood Estimation of a Complete System of Demand Equations." *European Economic Review* 1(1969): 7-73.

Barten, A.P. "The Systems of Consumer Demand Functions Approach: A Review." *Econometrica* 45(1977): 23-51.

Beach, Charles M., & James G. MacKinnon "Maximum Likelihood Estimation of Singular Equation Systems with Autoregressive Disturbances." *International Economic Review* 20(1979): 459-64.

Berndt, Ernst R., & N. Eugene Savin "Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances." *Econometrica* 43(1975): 937-58.

Bewley, Ronald *Allocation Models Specification, Estimation, and Applications.* Cambridge, MA: Ballinger, 1986.

Burgess, David F. "A Cost Minimization Approach to Import Demand Equations." *The Review of Economics and Statistics* 56(1974a): 225-34.

Burgess, David F. "Production Theory and the Derived Demand for Imports." *Journal of International Economics* 4(1974b): 103-17.

✓ Central Intelligence Agency (CIA). *World Factbook 1999.* Washington D.C., 1999. www.odci.gov/publications/factbook.

Diewert, W. Erwin & Catherine J. Morrison "Export Supply and Import Demand Functions: A Production Theory Approach." In *Empirical Methods for International Trade,* Robert C Feenstra ed., Cambridge, MA: MIT Press, 1989.

Dobson, William D. "The Deregulation of the U.S. Dairy Industry: Implications for World Dairy Markets." *Agribusiness* 8(1992): 457-471.

Dobson, William D. "Prospects for U.S. Dairy Exports." University of Wisconsin-Madison, Department of Agricultural Economics Staff Paper No. 382, Madison, 1995.

Dobson, William D. "When will U.S. Firms Become Major Dairy Exporters?" Marketing and Policy Briefing Paper University of Wisconsin-Madison, Department of Agricultural Economics Paper No. 57, Madison, 1997.

Dobson, William D. & Robert A. Cropp "Economic Impacts of the GATT Agreement on the U.S. Dairy Industry." University of Wisconsin-Madison, Department of Agricultural Economics Staff Paper No. 50, Madison,1995.

Food and Agricultural Organization of the United Nations Statistics (FAO Statistics). Rome, Italy, 1999. www.fao.org.

Gardner, Bruce L. *The Economics of Agricultural Policies.* New York, NY: Macmillan, 1987.

General Agreements on Tariffs and Trade. (GATT) *Trade Policy Review Japan Volume 1* Geneva, Switzerland: GATT, 1992.

General Agreements on Tariffs and Trade. *Trade Policy Review Mexico Volume 1* Geneva, Switzerland: GATT, 1992.

General Agreements on Tariffs and Trade. *Trade Policy Review Japan Volume 1* Geneva, Switzerland: GATT, 1995.

Green, Richard D., Zuhair A. Hassan, & Stanley R. Johnson "Maximum Likelihood Estimation of Linear Expenditures Systems with Serially Correlated Errors." *European Economic Review* 11(1978): 207-19.

Greene, William H. *Econometric Analysis.* Upper Saddle River, NJ: Prentice Hall, 1997.

Griffin, Michael "Outlook for the Dairy Sector to the Year 2005." International Symposium on International Prospects for Dairying in the Next WTO Negotiating Round, June 3-4, Rome, Italy, 1999.

Hall, Bronwyn H. & Clint Cummins *Reference Manual Version 4.4.* Palo Alto, CA: TSP International, 1998.

Harvey, Andrew *The Econometric Analysis of Time Series.* 2nd ed. Cambridge, MA: MIT Press, 1993.

Japan Dairy Council. *Japan Dairy Farming for Yesterday, Today, Tomorrow*. Tokyo, Japan: Japan Dairy Council, 1999. Jdc.lin.go.jp/dairy/farm01.htm.

Kohli, Urich R. "A Gross National Product Function and the Derived Demand for Imports and Supply of Exports." *Canadian Journal of Economics* 11(1978): 167-82.

Kastens, Terry L. & Gary W. Brester "Model Selection and Forecasting Ability of Theory-Constrained Food Demand Systems." *American Journal of Agricultural Economics* 2(1996): 301-12.

Kohli, Urich R. *Technology, Duality and Foreign Trade: The GNP Function Approach to Modeling Imports and Exports.* Wheatsheaf, NY: Havester, 1991.

Konandreas, Panos *Next Round of Negotiations in Agriculture with Special Reference to the Dairy Sector*. Geneva, Switzerland: Food and Agriculture Organization of the United Nations, 1999.

Laitinen, Kenneth "Why Is Demand Homogeneity So Often Rejected?" *Economics Letters* 1(1978): 187-91.

Laitinen, Kenneth *The Theory of the Multiproduct Firm.* New York, NY: North Holland Publishing Company, 1980.

Laitinen, Kenneth & Henri Theil "Supply and Demand of the Multiproduct Firm." *European Economic Review* 11(1978): 107-54.

Lee, J.-Y., J.L. Seale, Jr., & P.A. Jierwiriyapant "Do Trade Agreements Help U.S. Exports? A Study of the Japanese Citrus Industry." *Agribusiness* 6(1990): 505-14.

Mas-Colell, Andreu, Michael D. Whinston, & Jerry R. Green *Microeconomic Theory.* New York: Oxford University Press, 1995.

Meilke, Karl & Sylvain Lairvere "The Problem and Pitfalls in Modeling International Dairy Tarde Liberalization." International Agricultural Trade Research Consortium. Working Paper Number 99-3, College Station, Texas, 1999.

McElroy, M.B."Goodness of Fit for Seemingly Unrelated Regressions." *Journal of Econometrics* 6(1977): 381-87.

Organization for Economic Co-operation and Development (OECD). *The Uruguay Round A Preliminary Evaluation of the Impacts of the Agreement on Agriculture in the OECD Countries.* Paris: OECD, 1995.

Pana-Cryan, Regina *Egyptian Import Demand for United States Wheat.* Ph.D dissertation University of Florida, Gainesville, 1996.

Parks, Richard W. "Systems of Demand Equations: An Empirical Comparison of Alternative Functional Forms." *Econometrica* 37(1969): 629-50.

Rougier, Jonathan "A Simple Necessary Condition for Negativity in the Almost Ideal Demand System with the Stone Price Index." *Applied Economics Letters* 4(1997): 97-99.

Seale, James L. Jr., Amy Sparks & Boyd M. Buxton "A Rotterdam Application to International Trade in Fresh Apples: A Differential Approach." *Journal of Agricultural and Resource Economics* 17(1992): 138-49.

Simpson, James R. "Japan's Dairy Industry-Mirror of the U.S.?" International Working Paper Series, Food and Resource Economics Department, University of Florida, Gainesville, 1993.

Theil, Henri *Principles of Econometrics.* New York, NY: John Wiley and Sons, 1971.

Theil, Henri "The Independent Inputs of Products." Center for Mathematical Studies in Businss and Economics, Report 7735, University of Chicago, 1975.

Theil, Henri "The Independent Inputs of Production." *Econometrica* 6(1977): 1303-27.

Theil, Henri *The System-Wide Approach to Microeconomics.* Chicago, IL: TheUniversity of Chicago Press, 1980.

Truett, Lila J. & Dale B. Truett "The Demand for Imports in Korea: A Production Analysis Approach." *Journal of Development Economics* 56(1988): 97-114.

U.S. Dairy Export Council (USDEC) *Comprehensive Reference Document on World Dairy Trade* Arlington, VA: USDEC, 1996.

U.S. Dairy Export Council. "World Trade in Powder Markets: A U.S. Perspective." *World Dairy Trade Markets and Outlook.* 2(2)(1997a): 1-4.

U.S. Dairy Export Council. "World Trade in Powder Markets: Trade Analysis of the Mexican Dairy Market." *World Dairy Trade Markets and Outlook.* 2(3)(1997b): 1-4.

U.S. Dairy Export Council. "Export Competition: A Profile of Australia and New Zealand." *World Dairy Trade Markets and Outlook.* 2(4)(1997c): 1-4.

U.S. Dairy Export Council. "Trade Prospects in Japan." *World Dairy Trade Markets and Outlook*. 3(1)(1998a):1-4.

U.S. Dairy Export Council. "Economic Impact from Increased Dairy Exports." *World Dairy Trade Markets and Outlook*. 3(2)(1998b): 1-4.

U.S. Dairy Export Council. "Dairy Export Subsidies and the WTO Canada Case." *World Dairy Trade Markets and Outlook*. 3(4)(1998c): 1-4.

U.S. Dairy Export Council. "World Milk Supply Conditions Beyond 2000." *World Dairy Trade Markets and Outlook*. 3(6)(1998d): 1-4.

U.S. Dairy Export Council. "World Demand for Dairy Products Beyond 2000." *World Dairy Trade Markets and Outlook*. 4(1)(1999a): 1-4.

U.S. Dairy Export Council. "International Trade Outlook for Dairy Products." *World Dairy Trade Markets and Outlook*. 4(2)(1999b): 1-4.

U.S. Department of Agriculture-Foreign Agricultural Service (USDA-FAS). *NAFTA Agricultural Fact Sheet: Milk Powder and Cheese*. Washington, D.C.,1998a. www. fas.usda.gov/itp/policy/gatt/com-fact-sheets.html.

U.S. Department of Agriculture-Foreign Agricultural Service. *Commodity Fact Sheets*. Washington, D.C., 1998b. www. fas.usda.gov/itp/policy/gatt/com-fact-sheets.html.

U.S. Department of Agriculture-Foreign Agricultural Service. *The North American Free Trade Agreement*. Washington, D.C., 1998c. www.fas.usda.gov/itp/policy/nafta/nafta.html.

U.S. Department of Agriculture-Foreign Agricultural Service *Policy and Programs Development Highlights*. Washington, D.C., 1999a. www.fas.usda.gov/dlp/circular/1999/99-07Dairy/policy.html.

U.S. Department of Agriculture-Foreign Agricultural Service. *Japan Dairy Japanese Dairy Sector Reform 1999*. Report number JA9103, Washington, D.C., 1999b

U.S. Department of State. "Hong Kong." *Country Reports On Economic Policy and Trade Practices*. Washington, D.C., 1997.

Uzawa, Hirofumi "Production Functions with Constant Elasticities of Substitution." *The Review of Economics Studies*, 29(1962): 291-99.

Vitaliano, Peter "The Future Direction of the U.S. and World Dairy Industry After the Uruguay Round GATT Agreement." National Milk Producers Federation, Arlington, VA, 1995.

World Trade Organization (WTO). *Trade Policy Review Mexico 1997*. Geneva, Switzerland: WTO, 1997.

World Trade Organization. *Trade Policy Review Hong Kong, China 1998*. Geneva, Switzerland: WTO, 1998a.

World Trade Organization. *Trade Policy Review Japan 1998*. Geneva, Switzerland: GATT, 1998b.

Zellner, Arnold "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *American Statistical Association Journal.* (1962): 348-68.

Zhang, Ping, Stanley M. Fletcher and Dale H. Carley "Japan's Peanut Import Demand: Implications for United States Exports." *Agricultural Economics* 11(1994): 51-59.

Zhou, Meng and Andrew M. Novakovic "Exporting to China: Possibilities and Challenges for U.S. Dairy Industry." *Agribusiness* 12(1996): 1-13.

Zhou Ying, Tom Cox and Jean-Paul Chavas "Spatial Equilibrium Analysis of Trade Liberalization and the U.S. Dairy Sector." NRI Grant Number 94-37400-0966. Madison, WI, 1998.

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